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WHAT YOU NEED TO KNOW
AND HOW WE'LL
GET THERE

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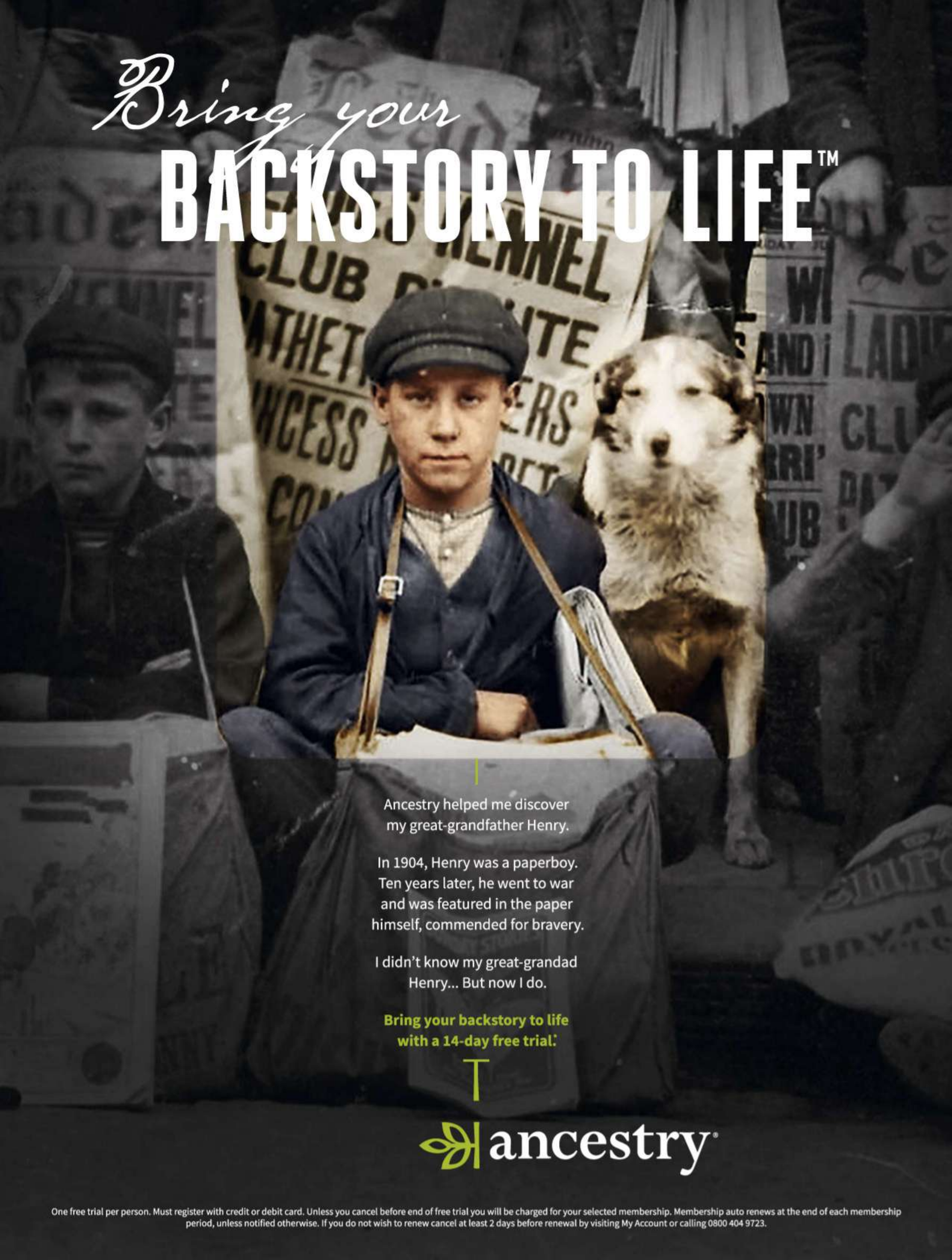
Smart Home
How to buy the right internet-connected doorbell

Human Body
Is there a limit to how much you can eat?

Face Masks
Why wearing them changes our behaviour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FROM THE EDITOR

Why are there so many different COVID-19 symptoms? Why do some people seem to get it without experiencing sickness at all? How are some people already immune to the disease? There are still so many questions surrounding COVID-19 and how it affects our bodies. We're witnessing what happens to our immune systems when it's introduced to a completely new, and aggressively infectious, disease.

The truth is our immune systems aren't as straightforward as we like to think. Over millions of years, our bodies have collectively learned to shield themselves from many of the microorganisms we share our lives with, with modern medicine bolstering our defences in the last century. But, faced with something totally novel, we can see exactly how delicately complex our immune system is. The good news is that scientists are discovering the intricacies of how our bodies deal with COVID-19 at an unprecedented speed. Find out what we've discovered so far and why there are reasons to be hopeful over on p48.

Also if you want to read the latest news on the pandemic, and the efforts to create a vaccine, be sure to sign up to our daily newsletter **sciencefocus.com/newsletter.**

Enjoy the issue…

Daniel Bennett, Editor

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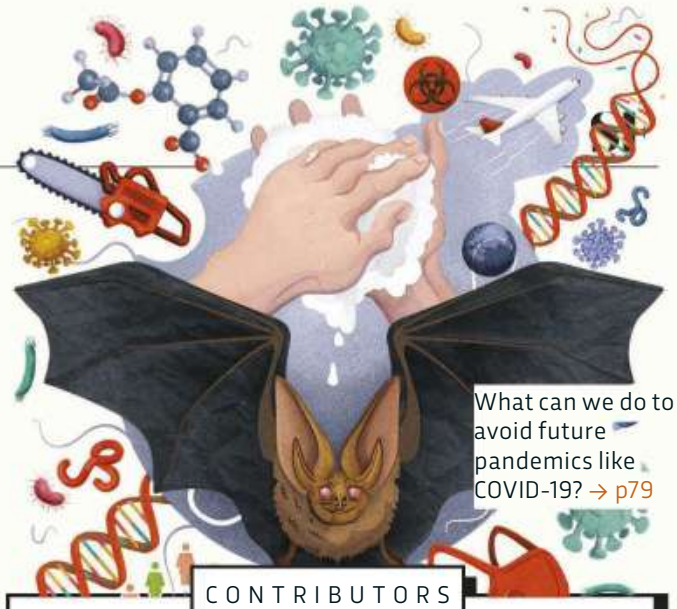

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JAMES ROMERO
To set up a permanent residence on Mars, we'll need a sustainable food source. James investigates the researchers planning to turn the Red Planet green. →p60

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ON THE BBC THIS MONTH...

The Life Scientific
Jim Al-Khalili speaks to Prof Sarah Gilbert (pictured), who is leading the team at Oxford University that's searching for a COVID-19 vaccine candidate.
BBC Radio 4, 15 September, 9am and 9:30pm

The Diagnosis Detectives
In this four-part series, Dr Michael Mosley and a team of leading experts investigate the medical mysteries that have previously baffled other doctors.
Episode one available on BBC iPlayer

Inside Science – COVID Special
What will be the long-term health impacts of COVID-19? Dr Adam Rutherford will explore what we think, what we don't yet know, and how we'll find out more.
BBC Radio 4
17 September, 9pm

COVER: ANDY POTTS THIS PAGE: BBC X2, GETTY IMAGES

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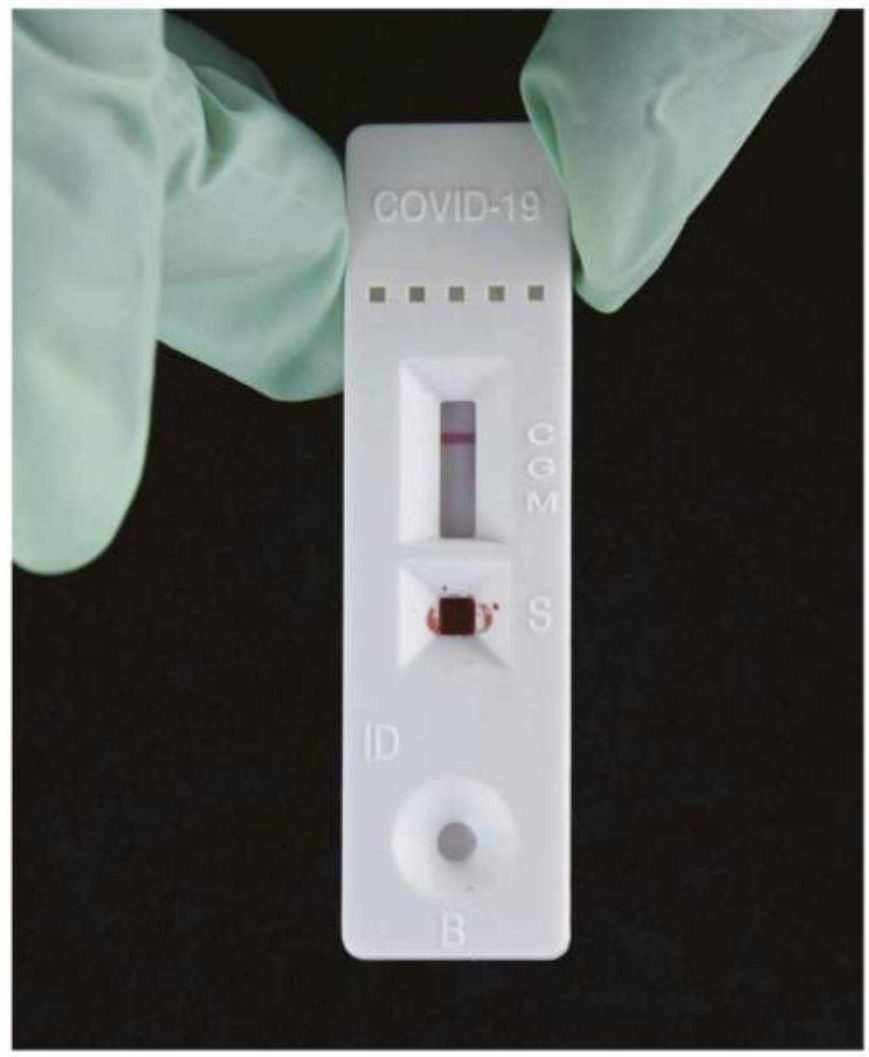

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"TEACHERS PROVIDE OUR KIDS WITH THE SKILLS TO SUCCEED IN LIFE. WE CANNOT ATTACK THEM. BUT WE DO"

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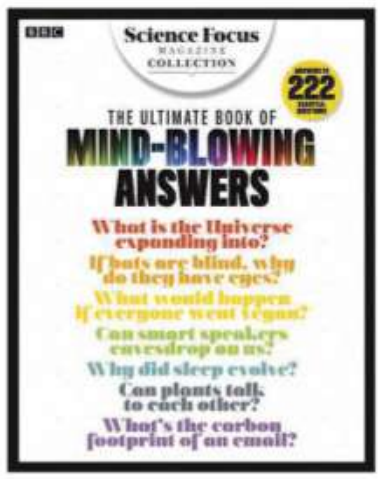
SPECIAL ISSUE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Why did sleep evolve?
Can plants talk to each other?
What's the carbon footprint of an email?

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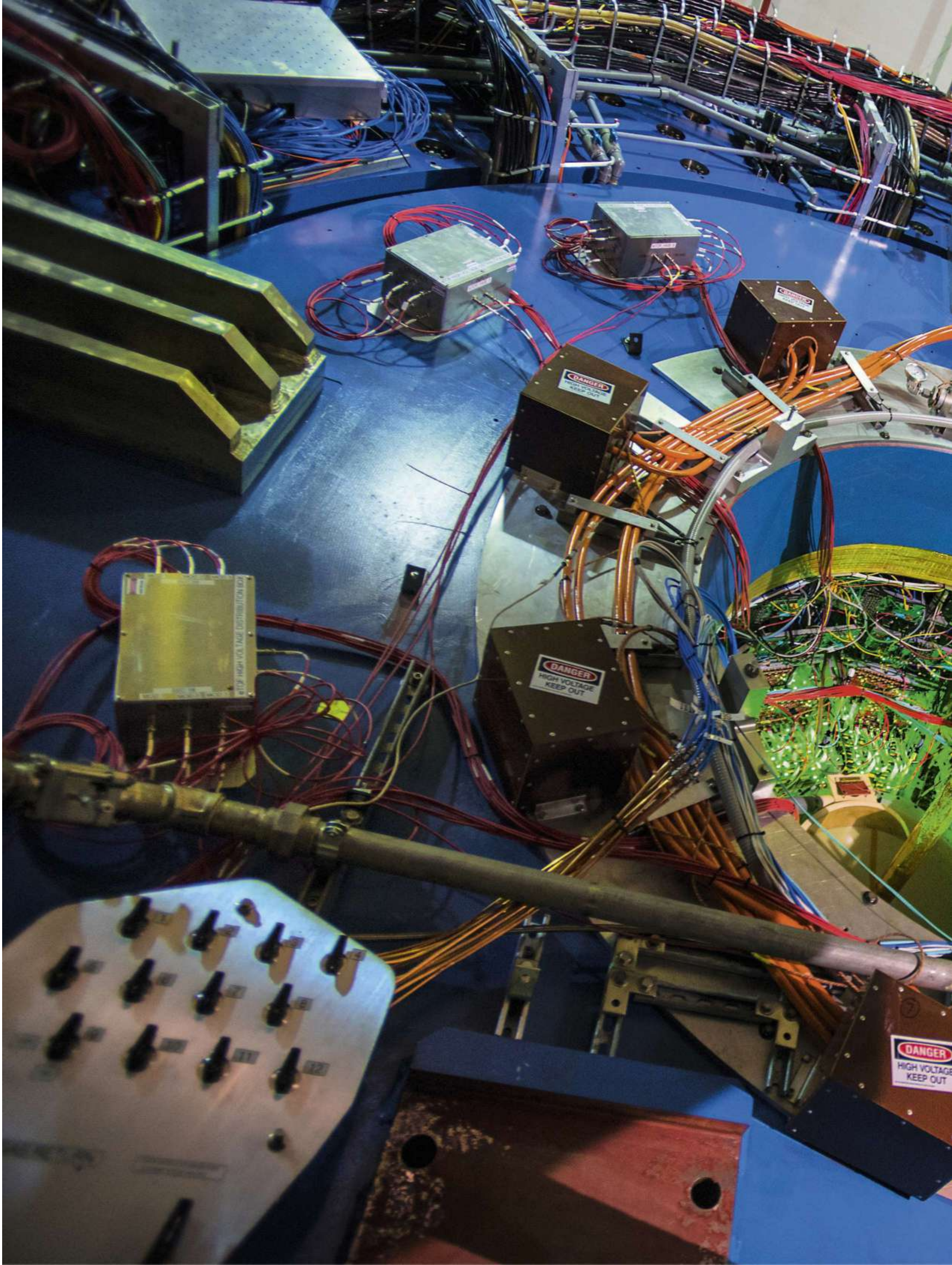
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EYE OPENER

This matters

NEW YORK, USA

Weighing 1,200 tonnes and as large as a house, this is the Solenoidal Tracker (STAR). One of four experiments at the Relativistic Heavy Ion Collider (RHIC), it tracks the thousands of particles produced by ion collisions at the RHIC, which is capable of colliding ions as atomically heavy as gold.

These collisions have resulted in the creation of quark-gluon plasma (QGP), which has been hailed as the 'perfect liquid'. Reaching temperatures of four trillion degrees Celsius – many thousands of times hotter than the centre of the Sun – this perfect liquid provides a rare glimpse of the hot, dense states of matter that existed microseconds after the Big Bang. As the Universe cooled, the quarks and their gluon bonds coalesced into subatomic protons and neutrons, which constitute the nuclei of atoms that make up all ordinary matter today.

Physicists hope that by understanding QGP, we may better understand the early Universe itself.

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CONVERSATION

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LETTER OF THE MONTH

Cold shoulders

I thought the 'Cold comfort' article (July, p74) was very interesting! A cold shower – about 7°C, as cold as the tap allows – is now part of my daily routine, which I believe has had a profound effect on my health. One of the benefits is a greater mental toughness: once I've convinced myself that the cold blast will be worth it and endured the freezing, breathless few minutes that follow, I've overcome two psychological obstacles, which makes for a great start to the day!

Do you think that regular cold showers could be as beneficial as a dip in the sea, as adapting to the shock of cold water is key to both scenarios?

Nick Griffiths, *Cardiff*

I talked to environmental physiologist Mike Tipton about this exact topic. He said, "cold water immersion is better for you than a cold shower, because you get cold faster, but it's just regular immersion that's important."

So you may well be getting the same benefits from your cold showers, but the regularity is more important than the method. Although I couldn't find any instances of this being tested scientifically, many of the swimmers I've interviewed about cold water immersion cite exactly the same thing as you do – it imparts a mood-boosting sense of achievement and self-belief. Keep it up, however you choose to do it!

Helen Glenny, *science journalist*

WRITE IN AND WIN!

The writer of next issue's *Letter Of The Month* wins a **Chipolo bundle, with two Chipolo One tags and one card**. The tags can be attached to your belongings, including your keys, bag, or even a child's favourite toy, while the card is perfect for slotting into your wallet or passport cover. If you misplace something, simply use the Chipolo app to 'ring' the item to help you find it. If you're out of Bluetooth range, the app will let you know where you last had it. **chipolo.net**

The dirtier sex?

While reading the article about post-coronavirus workplaces (July, p30), I'm curious to know why the soap dispenser in the women's toilet featured in the 'Top 5 Dirtiest Spots around the office' rather than soap dispensers in general. Is it because men are less likely to handle soap? Or is there another reason behind this?

Shannon Ripsher

I'm afraid we really aren't sure why the women's soap dispenser tested positive at a higher rate than the men's. It would be interesting to study this result in more detail!

Kelly Reynolds, *professor of public health and environmental science*

Can anyone help?

What breed/breeds of dog is the third one from left on the cover of your July issue? I have a rescue dog that looks very similar to that one, but haven't been able to properly identify her mixture of breeds!

Garrett Hinson

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FASTER-THAN-LIGHT TRAVEL IS WARP DRIVE REALLY POSSIBLE?
Science Focus
Secrets of a ROLLERCOASTER DESIGNER
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The feel-good issue
HOW DOGS CAN HELP US LIVE HEALTHIER, LONGER LIVES
OUR BEST FRIENDS' BIOLOGY COULD HOLD THE KEY TO AGEING WELL
Immune System
The Genome
Coronavirus

"THE EMOTIONAL LABOUR OF HOLDING OUR ANXIETY AND STRESS – NOT TO MENTION OUR KIDS' – IS HEAVY WORK, AND NOT WHAT TEACHERS SIGNED UP FOR"

ALEKS KROTOSKI, p58

A towering effect

In the July issue (p87) you ask the question 'Are humans to blame [for global warming]?' The answer is illustrated by a photograph of power station cooling towers. These towers are purely emitting water vapour making man-made clouds, which may, if anything, shield out the Sun and reduce land temperatures. They do not add to the greenhouse effect.

David Paylor, *CEng MiET, Oxford*

The picture did indeed show cooling towers, which, as you point out, emit water vapour. This still has an impact on global temperatures, however.

Clouds do block sunlight and reflect it back out to space, cooling the Earth in the process. But they also trap warmth radiating from the Earth's surface and retransmit it back down towards its origin, increasing temperatures. Of course, this differs between cloud types and, currently, the net effect is reducing temperatures of the Earth.

But climate change will have an impact on the number and type of clouds that form. Most climate models agree that these changes in clouds will have the net effect of amplifying rising temperatures.

You can read more about this from our Q&A expert Alexandra Franklin-Cheung here: bit.ly/clouds-climate

Amy Barrett, editorial assistant

In support of Earth...

I fully agree with Peter Harris's letter in the July edition (p10) suggesting that we stop looking up and start looking down. I recently read Carl Sagan's excellent book *Cosmos* and it left me pondering the eye-watering amount of public money that's spent on space.

No doubt, Peter Harris's detractors will point to the advantages already gained from space exploration. But I believe these are all achieved in the first 22,000 miles (roughly 10 per cent of the distance to the Moon). Those same people will probably say we have to keep going forward, or else we'll go back.

I'm sure Peter Harris and I could fill this magazine with things to fix here on Earth, all of which would make bringing back a scoop of rock from Mars look very easy.

John Harris

GETTY IMAGES X2

... In support of exploration

I couldn't believe Peter Harris's comment that scientific exploration of space is of little use to our lives here on Earth.

A quick check reveals the following benefits (of which there are many more): CAT scanners used in medicine, scratch-resistant lenses in glasses, foil blankets used in mountain rescues, low-power LEDs, trainers, water-purification units, ear thermometers, wireless headsets , freeze-dried foods, Teflon, portable computers and many computer accessories no doubt all used by Peter on a daily basis. Perhaps we should be studying the Bible and Greek mythology instead? Doing either of those, in my opinion, would be useless.

Julian Halls, *Norfolk*

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ED YONG, author of *I Contain Multitudes*

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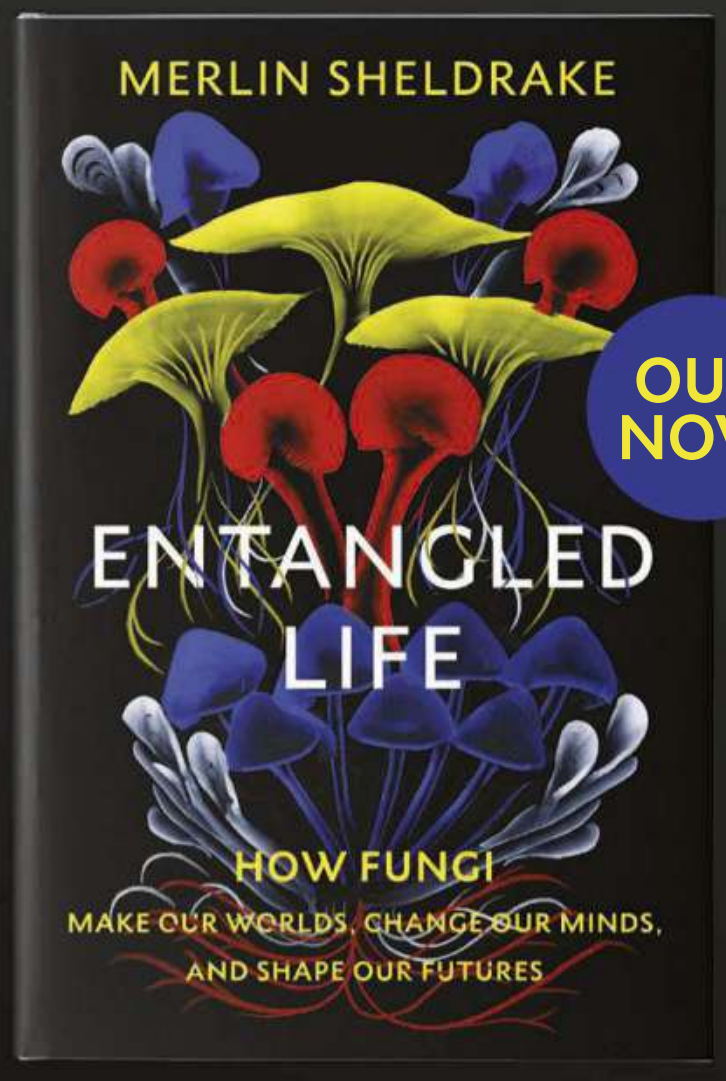

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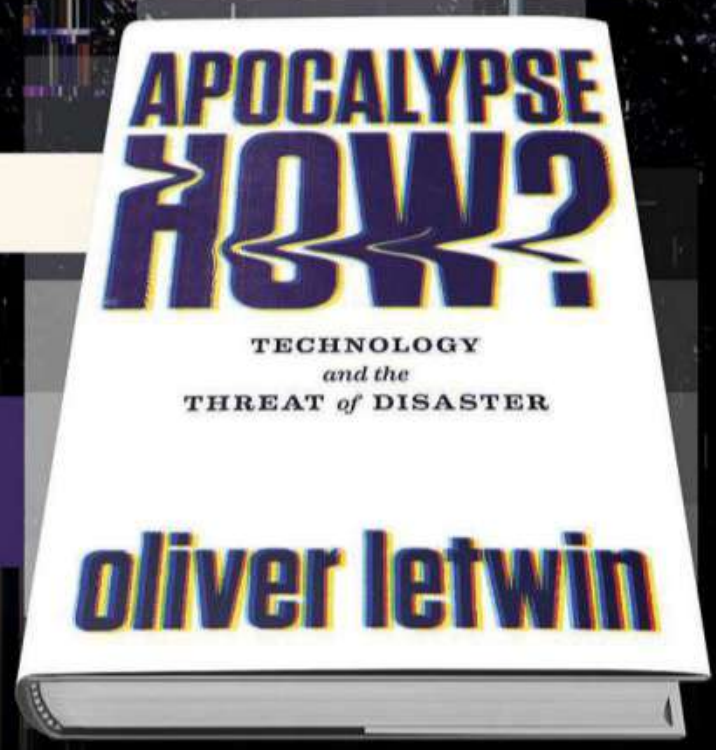

'Reads like a dystopian thriller, but the dangers are very real.'

MARTIN FORD, AUTHOR OF *THE RISE OF THE ROBOTS*

'Masterful, disturbing and informed… should be mandatory reading'

PROFESSOR RICHARD SUSSKIND OBE, OXFORD INTERNET INSTITUTE

OUT NOW

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DISCOVERIES

ARCTIC SEA ICE COULD DISAPPEAR BY 2035

The latest climate study highlights the immediacy of tackling climate change, researchers say

Scientists examine melt ponds in the Arctic, which form as the ice melts and fresh water collects in depressions

NASA/GSFC

Humans are not to blame Climate warming is likely cause of woolly rhino extinction p15 **Happiness injections?** Clinicians have found a correlation between Botox and easing depression p17 **Caught in the act** Preserved ancient hell ant found attacking its prey p18

News in brief

MEDITATION MAY AID SLEEP PARALYSIS

Sleep paralysis – a condition affecting one in five of us and thought to explain several mysterious experiences including alien abduction and demonic night-time visits – could be treated using meditation-relaxation techniques, a study from the University of Cambridge has found.

During a bout of sleep paralysis, the sufferer is rendered temporarily unable to move, just on the onset of sleep or waking, but remains acutely aware of their surroundings. The episodes are frequently accompanied by visions of dangerous bedroom invaders such as aliens or ghosts.

The team found that episodes more than halved over a period of eight weeks, if during an attack, patients reminded themselves that the episode would pass, that there was no need to be afraid, and by relaxing their muscles.

A polar bear stands on melting sea ice in Nunavut, Canada

During spring and early summer as the seasonal temperatures rise, shallow pools of water form on the surface of Arctic sea ice. These so-called 'melt ponds' are important for the ice's albedo – a measure of how much sunlight is absorbed by the ice and how much is reflected into space. This is key because larger areas of melt ponds accelerate the melting. They are darker than sea ice and so absorb more solar heat, which causes the melt ponds to grow, creating a larger area to absorb even more heat.

Now, an international team of researchers, headed up by the British Antarctic Survey (BAS), have used a cutting-edge climate modelling system developed by the UK Met Office's Hadley Centre to estimate that intense spring sunshine has created a larger number of melt ponds, and may leave summer months in the Arctic ice-free in as little as 15 years.

The team based their predictions on data gathered on the last interglacial, a phase of relatively warm temperatures – lasting thousands of years – in between glacials. The current interglacial period began at the end of the Pleistocene, around 11,700 years ago.

> "We should focus on achieving a low-carbon world as soon as humanly feasible"

"High temperatures in the Arctic have puzzled scientists for decades. Unravelling this mystery was technically and scientifically challenging. For the first time, we can begin to see how the Arctic became ice-free during the last interglacial," said joint lead author Dr Maria Vittoria Guarino, an Earth system modeller at the British Antarctic Survey (BAS). "The advances made in climate modelling means that we can create a more accurate simulation of the Earth's past climate, which, in turn, gives us greater confidence in model predictions for the future."

The finding highlights the importance of incorporating melt pond data into climate models and tackling climate change as a matter of urgency, the team say.

"We know the Arctic is undergoing significant changes as our planet warms. By understanding what happened during Earth's last warm period we are in a better position to understand what will happen in the future," said Dr Louise Sime, the group head of the Palaeoclimate group and joint lead author at BAS. "The prospect of the loss of sea-ice by 2035 means we should really be focusing all our minds on achieving a low-carbon world as soon as humanly feasible."

CHOCOHOLICS

Eating chocolate at least once a week could help to reduce the risk of heart disease by as much as 8 per cent, a team at Baylor College of Medicine, Houston has found. The effect is thought to be due to nutrients in the chocolate, such as flavonoids, reducing inflammation and increasing good cholesterol.

WINE LOVERS

Researchers at the University of California, Riverside have successfully mapped out the genome of phylloxera, an aphid-like pest capable of decimating vineyards. Scientists now hope to genetically engineer phylloxera-resistant grapevines. We'll drink to that!

Good month

Bad month

MUSICIANS

Music training during a young age doesn't appear to benefit a child's academic performance, an analysis of 54 previous studies from Fujita Health University, Japan has found.

BIKE THIEVES

Researchers from Durham University and the Fraunhofer Institute claim to have manufactured the world's first non-cuttable material. Dubbed proteus, vibrating spheres chip away at the cutting edge of the tool and quickly render it too blunt to cut further.

GETTY IMAGES X2, ARIANNE PORLA ILLUSTRATIONS: CATHAL DUANE

A researcher collects tears from a broad-snouted caiman

ZOOLOGY

Bird and reptile tears are similar to our own

From an anatomical point of view, we're pretty different from birds and reptiles, but it turns out that our tears share remarkable similarities.

Tears are not simply made up of water, but contain other substances like sodium, calcium, urea, chloride and proteins. While tears play an important role in eye health, until now they had only been analysed in a few mammal species. A team led by Prof Arianne Oriá, from Brazil's Federal University of Bahia, wanted to get a better picture of how tears work in other animals, so they studied various reptile and bird species, including macaws, owls, hawks, a type of parrot, caimans, tortoises and sea turtles.

"Although birds and reptiles have different structures that are responsible for tear production, some components of this fluid are present at similar concentrations as what is found in humans," said Oriá.

The researchers found that all the bird and reptile tears had similar amounts of electrolytes to human tears, but the owl and sea turtle tears contained higher levels of urea and protein. After studying the tear composition, the team allowed the tears to dry out and studied the crystallisation patterns that formed. These patterns can be used to detect certain eye diseases, along with other variations in the tears. Surprisingly, although the tears all showed similar compositions, the crystals displayed more variety. The caiman and sea turtle tears were particularly unique, which may be an adaptation to keeping the eyes healthy in the reptiles' watery habitats.

Further research in this field could help boost our understanding of tear types, and therefore lead to improved treatments for animals and humans to optimise eye health.

"This knowledge helps in the understanding of the evolution and adaption of these species, as well as in their conservation," said Oriá.

ONE-SIZE-FITS-ALL APPROACH TO DRUG PRESCRIPTION IS FAILING WOMEN

Women are more likely than men to suffer adverse side effects of medications because drug dosages are based on clinical trials conducted on men, a study from the University of California, Berkeley, and the University of Chicago suggests.

The researchers analysed data from several thousand medical journals and found clear evidence that women were being overprescribed for 86 different medications approved by the Federal Drug Administration (FDA), including antidepressants, cardiovascular and anti-seizure drugs and analgesics, among others.

In more than 90 per cent of cases, women experienced worse side effects, such as nausea, headache, seizures, depression, cognitive deficits, hallucinations, agitation and cardiac anomalies, and were found to experience adverse reactions nearly twice as often as men.

3D PRINTING

Dig this: the soil in your garden could build your next home

Your next home could be made of mud! By extracting the clay component from soil and mixing it with sodium silicate, researchers from Texas and San Francisco were able to produce a material that could flow easily through a 3D printer, but hardens quickly to form a strong, load-bearing structure.

The composition of a soil sample can vary greatly, containing any mixture of clay, rock and organic material. So, the researchers aimed to develop a tool that would turn any type of soil into a useable 'ink' for 3D printing.

They say that after a quick analysis of the soil, their toolkit could figure out how much sodium silicate was needed to be added to the sample, in order to turn it into a printable building material.

The ability to 3D print buildings has been around for a few years, with large robots using concrete to create frameworks for houses. However, many are concerned with the environmental impact of relying on concrete – it's estimated that 7 per cent of global carbon dioxide emissions come from the cement industry, and it's not currently possible to recycle the building material.

"The environmental impact of the construction industry is an issue of growing concern," said Sarbajit Banerjee, principal investigator on the clay-based 3D printing project. "Some researchers have turned to additive manufacturing, or building structures layer by layer, which is often done with a 3D printer. That advance has begun to transform this sector in terms of reducing waste, but the materials used in the process need to be sustainable as well," he cautioned.

With the new technique, structures can be 3D printed from local soil

> "The materials used in 3D printing need to be sustainable"

The team say that using a local soil source can cut transport emissions while helping the surrounding community. The technology is also of interest for those in extreme or hostile environments to robotically print large-scale structures, say the researchers in their paper, such as building clinics in times of war or in disease-ridden jungles, or even in extra-terrestrial planetary environments such as Mars.

ALAMY, ALBERT PROTOPOPOV, AAYUSHI BAJPAYEE

The preserved, reconstructed remains of a baby woolly rhino, which was recovered from Siberian permafrost in 2015

PALAEONTOLOGY

Extinct woolly rhinos were a victim of climate change, not overhunting

By analysing their genetic diversity, scientists have been able to estimate changes in population size over time

The woolly rhinoceros was wiped out by warming temperatures, not hunting, a new study suggests.

About the same size as today's white rhino, the woolly rhinoceros was covered with thick, reddish-brown hair, and thrived throughout Europe, northern Asia and Siberia. They became extinct at around the same time as other prehistoric megafauna, including the woolly mammoth and the cave lion. It was previously proposed that hunting by humans had caused their demise, however, this hypothesis doesn't match up with recent discoveries.

"It was initially thought that humans appeared in northeastern Siberia 14,000 to 15,000 years ago, around when the woolly rhinoceros went extinct," explained study leader Prof Love Dalén, an evolutionary geneticist at the Centre for Palaeogenetics in Stockholm, Sweden. "But recently, there have been several discoveries of much older human occupation sites, the most famous of which is around 30,000 years old. So, the decline towards extinction of the woolly rhinoceros doesn't coincide so much with the first appearance of humans in the region."

Dalén and team studied the DNA from tissue, bone, and hair samples of

> "Their decline doesn't coincide with the first appearance of humans"

14 individual woolly rhinos. By analysing the genetic diversity of the genomes, the researchers were able to estimate changes in population size. For example, genetic diversity is reduced by inbreeding, which in turn suggests a smaller population.

The researchers found that the woolly rhino population increased around 29,000 years ago, remaining stable until the data ended at 18,500 years ago, long after humans arrived in the region. The team concludes that woolly rhino numbers must have declined between around 18,500 and 14,000 years ago, which overlaps with the Bølling–Allerød warming period.

"Although we can't rule out human involvement, we suggest that the woolly rhinoceros' extinction was more likely related to climate," said lead author, Edana Lord.

TIGER NUMBERS GROWING AT AN IMPRESSIVE RATE AROUND THE WORLD

Thanks to conservation efforts, wild tiger numbers are increasing in Bhutan, China, India, Nepal and Russia, the WWF reports. The boost in numbers has been particularly promising in India where the estimated number of animals has more than doubled, up to 3,350 since 2006 – that's about three-quarters of the world's tiger population.

"Ten years ago, tigers were in such a perilous state, that there was a very real risk of them becoming extinct in the wild," said Becci May, regional manager (Asian Big Cats) at WWF UK. "This is an achievement that not only offers a future for tigers in the wild, but for the landscapes they inhabit and the communities living alongside this iconic big cat."

Dogs appear to be able to detect changes in metabolic processes caused by COVID-19

EPIDEMIOLOGY

Dogs have been trained to sniff out patients with COVID-19

Thanks to their superior sense of smell, dogs have been trained to sniff out various diseases, including diabetes, malaria and tuberculosis. Now, new preliminary research led by the University of Veterinary Medicine, Hannover, suggests that dogs can also detect when people are infected with the SARS-CoV-2 virus, which causes COVID-19.

Currently, in order to detect COVID-19, a swab taken from someone's nose or throat is sent for testing. But this method can be time-consuming and costly, particularly in developing countries, which means that people are often only tested if they are showing symptoms.

According to the research, it took one week to train eight sniffer dogs to detect the virus, by presenting them with saliva samples and swabs taken from COVID-19 patients, as well as healthy people with no history of the disease. After training, the dogs were presented with 1,012 randomised samples and they correctly identified 157 positive samples and 792 negative samples, for an overall detection rate of 94 per cent.

"We think that this works because the metabolic processes in the body of a diseased patient are completely changed," said Prof Maren von Köckritz-Blickwede, who took part in the research. "We think that the dogs are able to detect a specific smell of the metabolic changes that occur in those patients." According to Köckritz-Blickwede, the next step will be to establish whether the dogs can differentiate between COVID-19 and other diseases, such as influenza.

While more research needs to be carried out, this preliminary study shows that the use of sniffer dogs could offer a quick, accurate way to detect COVID-19. The team has suggested that the technique could be particularly useful at airports, sports stadiums, mass gatherings and country borders, in order to help prevent outbreaks of the virus.

DOGS PROCESS SPEECH IN A SIMILAR WAY TO HUMANS

As anyone who has a canine companion in their life can attest, dogs are uncannily good at understanding what humans are trying to tell them. Now, a study from Eötvös Loránd University, Hungary, has found a clue as to why: dogs process speech in a way that's similar to humans. Researchers measured the changes in brain activity of awake, cooperative dogs to known praise words (clever, well done, that's it) and unknown, neutral words (such, as if, yet) using an fMRI scanner. They found that pooches process speech in the same hierarchical way as humans with the intonation or emotion of our voices being dealt with in the 'lower order' subcortical regions and the meaning of known words being dealt with in the 'higher order' cortical regions.

In numbers

13%

The proportion of people who are pathological liars (classified as telling around 10 lies a day), a study at Angelo State University has found.

710 MILLION

The amount, in tonnes, of plastic pollution predicted to be in the world by 2040, according to a study a group of international researchers published in the journal *Science*.

50%

The drop in human-linked vibrations in the Earth due to the COVID-19 lockdown between March and May 2020, as calculated by seismologists at Imperial College London.

EOTVOS LORAND UNIVERSITY, GETTY IMAGES X3

MEDICINE

Botox could help in the fight against depression

Botox, a medication derived from a bacterial toxin that's commonly injected to reduce the appearance of wrinkles, may help to reduce the symptoms of depression too, researchers at Skaggs School of Pharmacy and Pharmaceutical Sciences at University of California, San Diego have found.

The team of researchers mined the Adverse Effect Reporting System database, run by the US Food and Drug Administration, which lists unwanted effects from drugs. Out of more than 13 million voluntary drug reports, there were 40,000 from people receiving Botox injections for a range of conditions ranging from cosmetic treatments to migraines, muscle spasms and incontinence.

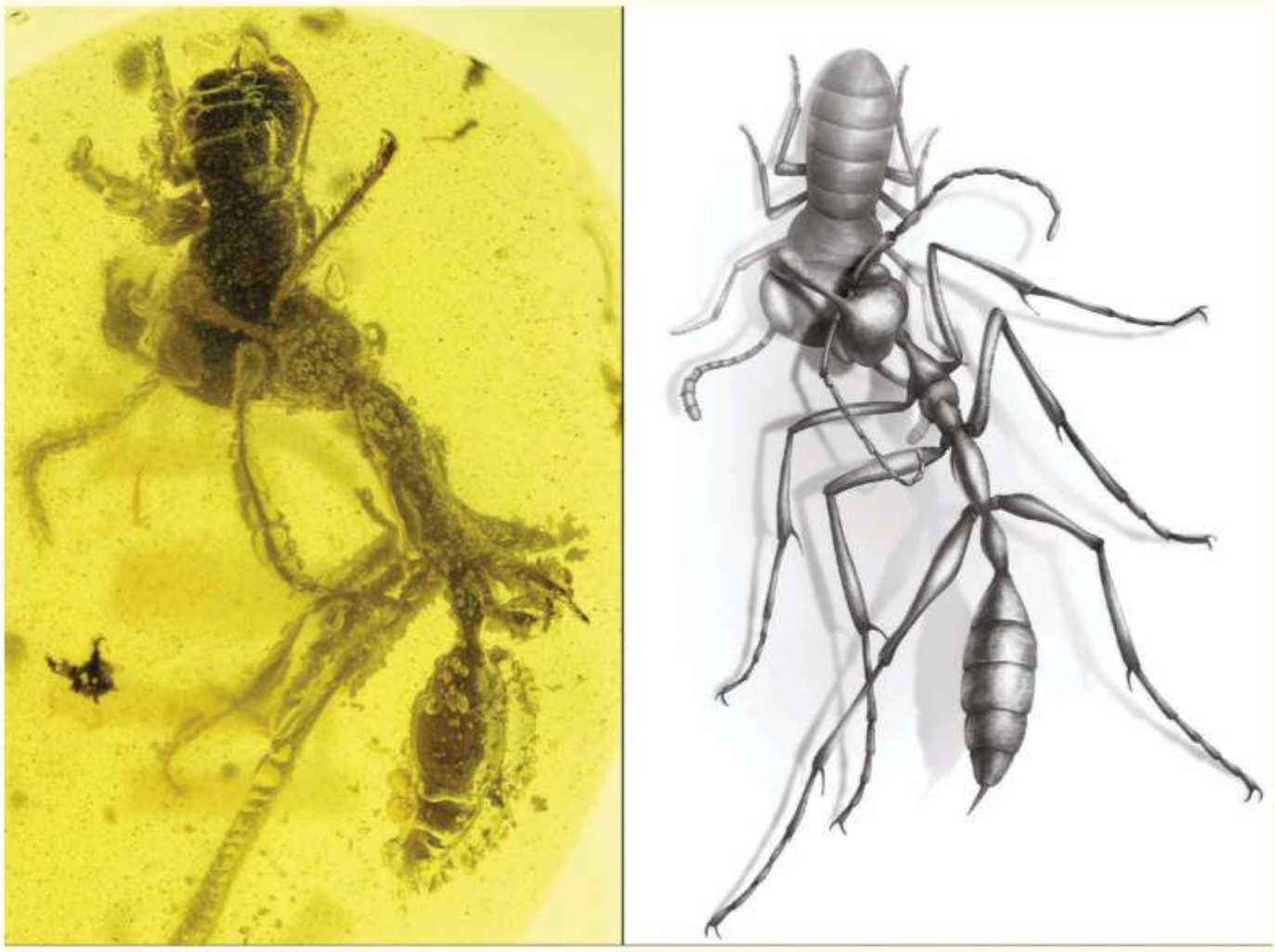
They discovered that people who had received Botox injections reported depression significantly less often than patients undergoing different treatments for the same conditions.

The team focused on reports covering Botox treatments in various sites, including the forehead, neck, limbs and bladder, and applied a mathematical algorithm to look for statistically significant differences between Botox users and patients who received different treatments for the same conditions. They found that depression was reported between 40 to 80 per cent less often by the Botox-treated patients.

"For years, clinicians have observed that Botox injected for cosmetic reasons seems to ease depression for their patients," said Prof Ruben Abagyan. "It's been thought that easing severe frown lines in the forehead region disrupts a feedback loop that reinforces negative emotions. But we've found here that the mechanism may be more complex, because it doesn't really matter where the Botox is injected."

Further research is now needed to determine the exact mechanism by which Botox is able to function as an antidepressant, though the team suspects that it could be transported to the regions of the central nervous systems involved in mood and emotions after injection. But since Botox is commonly used to treat chronic conditions that may contribute to depression, its success in relieving the underlying problem may, indirectly, also relieve symptoms of depression.

Current treatments, such as psychotherapy and selective serotonin reuptake inhibitors, are ineffective for nearly one-third of depression patients. It is therefore vital that other options, such as Botox injections, are investigated, the team says.



The hell ant grasping a cockroach in its mandibles, preserved in 99-million-year-old amber (left) and visualised illustratively (right)

PALAEONTOLOGY

Fossilised 'hell ant' shows how these ancient insects hunted

A stunning, 99-million-year-old fossil has captured a 'hell ant' (*Ceratomyrmex ellenbergeri*) in the act of attacking its prey. It provides rare evidence for how these extinct insects hunted with their scythe-like mandibles and horn-like headgear.

This particular hell ant specimen was preserved in amber found in Myanmar (formerly Burma), along with its unlucky insect prey, which is an extinct relative of the cockroach.

Like other species of hell ant, *C. ellenbergeri* sports a pair of deadly mandibles (jaws) that snap upwards in a vertical motion, unlike the mandibles of modern ants, which move horizontally. Also unlike modern ants, the hell ants have horns protruding from their heads.

The fossil provides the first piece of direct evidence that hell ants, which are believed to have become extinct along with the dinosaurs some 65 million years ago, used their headgear to hunt, snapping their mandibles to pin their prey against the horn.

"To see an extinct predator caught in the act of capturing its prey is invaluable," said study leader Dr Phillip Barden at New Jersey Institute of Technology in the US. "This fossilised predation confirms our hypothesis for how hell ant mouthparts worked. The only way for prey to be captured in such an arrangement is for the ant mouthparts to move up and downward in a direction unlike that of all living ants and nearly all insects."

Barden and his team think that the early ancestors of hell ants would have first gained the ability to move their mouthparts vertically, while the diverse horns evolved later. So far, 16 hell ant species have been identified; some of them had horns with serrated teeth, while one species is believed to have impaled its victims on a horn that was reinforced with metal.

The research team now hopes to find more ancient ant fossils, with the aim of understanding why hell ants went extinct, while their modern-day equivalents thrived.

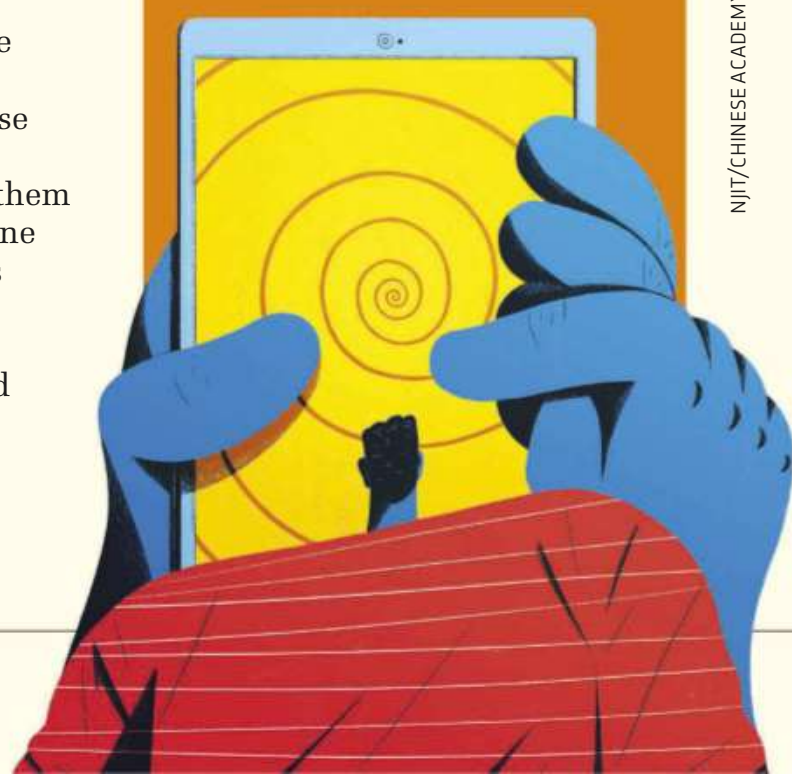
They did what?

Smartphone users hypnotised

WHAT DID THEY DO?
Psychologists at the University of McGill had more than 600 students with an average age of 21 listen to a 45-minute audio recording that was designed to induce hypnosis. Next, they were given 12 verbal suggestions such as 'you will momentarily be unable to open your eyes'. They were then taken out of hypnosis, and asked to complete a questionnaire detailing how many of the prompts they had followed. Next, they answered questions that assessed how much their phone use disrupts their normal lives and were given a score on the Smartphone Addiction Scale.

WHAT DID THEY FIND?
The higher a participant's score on the Smartphone Addiction Scale, the more likely they were to follow the hypnotic suggestions.

WHAT DOES THAT MEAN?
There was a small link between problematic smartphone use and hypnotisability. Hypnotisability and heavy smartphone use are both defined by absorbed states in which someone loses track of time and responds automatically to stimuli. The researchers suggest that interventions that target the absorbing effect of phones could encourage healthier use.



NJIT/CHINESE ACADEMY OF SCIENCES/UNIVERSITY OF RENNES, NASA, GETTY IMAGES ILLUSTRATIONS: CATHAL DUANE

TAKING VITAMIN D SUPPLEMENTS DOES NOT REDUCE RISK OF DEPRESSION

Researchers from universities and hospitals in America observed 18,353 adults aged 50 or older to see if taking vitamin D would help prevent them from developing depression.

Half of the participants took a vitamin D3 supplement, while the others took a placebo. None of the men or women involved in the study had depression at the start of the research. Throughout the five-year study, they were asked to fill in questionnaires, attend in-person psychiatric diagnostic interviews, and report any diagnosis of depression, or prescription of treatment for depression. By the end of the study, the risk of developing depression was not significantly different between the two groups.

SPACE

Distant stars could be home to up to seven habitable planets

Somewhere in the Universe, it is possible that there could be a star that's orbited by seven habitable planets, an astrobiologist at the University of California, Riverside, has calculated.

The search for life in outer space is typically focused on what scientists call the 'habitable zone' – the area around a star in which an orbiting planet could have liquid water oceans and conditions for life as we know it.

Dr Stephen Kane and his team created a model system in which they simulated planets of various sizes orbiting their stars. They used an algorithm that accounted for gravitational forces exerted by the host star and any orbiting planets, and tested how they would interact with each other over millions of years.

They found it is possible for some stars to support as many as seven habitable planets, and that a star like the Sun could potentially support six planets with liquid water – though the existence of Jupiter, a large gas giant, makes it impossible in our Solar System.

Currently, only a handful of stars are known to have multiple planets in their habitable zones, but Kane and his team now plan to search for stars surrounded by smaller planets. These stars will be prime targets for telescopes such as the one at NASA's Jet Propulsion Laboratory's Habitable Exoplanet Observatory, and could offer insight into forces that might change life on our own planet one day.

"Although we know Earth has been habitable for most of its history, many questions remain regarding how these favourable conditions evolved with time, and the specific drivers behind those changes," Kane said. "By measuring the properties of exoplanets whose evolutionary pathways may be similar to our own, we gain a preview into the past and future of this planet – and what we must do to maintain its habitability."

The TRAPPIST-1 solar system has three Earth-like planets in its habitable zone, but other stars could support as many as seven habitable planets

Adam Haar Horowitz (left) and Tomás Vega Biomedical engineers

Horizons

MIT researchers create wearable device that can influence the content of dreams

The technology could be used for further experiments into how dreams impact emotion, creativity, and memory

YOUR STUDY IS ABOUT 'TARGETED DREAM INCUBATION'. WHAT EXACTLY IS THAT?

AH: In short, the idea is that you could target specific content to be incubated in dreams, which is a kind of cheap explanation, but there's been a long history of trying to have subjects dream of something specific. Partially, the interest is clinical – we want to avoid nightmares, for example. Partially, it's therapeutic – we want people to help work through the more emotional side of some content. And partially it's memory-based – if you dream about something, you're going to remember it better when you wake up.

So there are all kinds of reasons to have someone dream about something specific, but it's failed pretty consistently for the past hundred years. What people have tried to do is show people some content while they're awake, and then wake them up four hours later in a REM cycle and see if they're dreaming about the thing they saw when they were awake.

The basic thing that our team did differently was to target this funny period, which is variably called 'covert REM' or 'Stage 1 sleep', that's right at the onset of sleep. It's a period that looks like REM sleep on EEG, and experientially it's also like REM sleep – you have dreams – but you're not fully unconscious; you don't have a sensory cut-off from the world and can still hear. Because we targeted that early period, it worked a hell of a lot better than past attempts at targeted incubation.

TELL US ABOUT THE WEARABLE DEVICE, DORMIO, THAT YOU DESIGNED FOR USE IN YOUR EXPERIMENTS.

TV: This new wearable has three sensors: it measures heart rate using an optical sensor; it measures electrothermal activity, which is a measure of arousal, using the conductivity between two electrodes on your skin; and it measures muscle tone through finger flexion. All of this is embedded in a glove-like wearable. Users are asked to close their hands when they go to sleep and, using a proprietary algorithm we developed at the MIT Media Lab, we then use these three different signals to show that the user is entering Stage 1 sleep, and we then play them audio cues.

WHAT KIND OF AUDIO CUES DID YOU USE?

AH: We've tried ambient sounds, so things like songs or environmental audio. But I think the thing that works best is a voice saying 'remember to think of elephants', for example. That engages the brain's task regions slightly, because you actually want people to wake up a little bit to regain some cognitive control so they can guide their dreams. The more

"I had Oompa Loompas singing and dancing around me, while I was swimming in lactose-free dark chocolate"

FLUID INTERFACES GROUP/MIT MEDIA LAB

MIT's glove-like wearable, Dormio, detects when someone is entering Stage 1 sleep, so the researchers can play them audio cues

something sounds like a task, the more it engages task regions. The task regions in the brain are cognitive control regions, but those are associated with wakefulness. So the type of cue that you deliver is going to influence the type of sleep state you put someone into. But if you leave them until the lip of Stage 2 sleep, people just go and dream about martial arts or whatever they want. In the same way that a lucid dream works, you need to engage some of those cognitive control regions. But you don't want them to be fully active because then you have a fully awake person. It's a kind of little seesaw.

YOU INITIALLY BEGAN EXPERIMENTING USING THE GLOVE ON YOURSELVES. WHAT KIND OF EXPERIENCE DID YOU HAVE?

TV: I wanted to dream about Oompa Loompas because I find them quite creepy. So I recorded myself saying 'Oompa Loompa doompety doo'. I believe that if it's your own voice you are more suggestible, because you trust your own voice. Then I was in hypnogogia [the state in which we begin dreaming before we fall fully unconscious] then I let myself drift on to Stage 2 sleep and then I asked myself through a second audio cue 'what are you dreaming about?' and I dreamt I was in a chocolate fountain, with a waterfall. But the cool thing was that it wasn't just chocolate, it was lactose-free, dark chocolate. That's quite interesting because I know consciously that I'm lactose-intolerant and I only eat dark chocolate. I already knew in my subconscious that I shouldn't eat milk chocolate. So, I had Oompa Loompas singing and dancing around me, while I was swimming in lactose-free dark chocolate.

I let myself drift again and was woken by a second audio cue asking me what I was dreaming about. And I was again in the lactose-free dark chocolate fountain, but I was programming. That was quite wild. Why would I be programming in a chocolate fountain? But I had just recently finished writing some code and uploaded it before I went to sleep, to see how there are more conscious behaviours embedded in these in these subconscious/conscious interaction.

YOU ALSO RAN A LARGER EXPERIMENT ON 50 PARTICIPANTS. WHAT DID YOU FIND?

AH: We showed two things. One, that we can reliably incubate specific content – for this study it was dreams of a tree. And the other was that if you take both objective and subjective measures of creativity, then people who do dream of trees perform better on creative tests with a theme of 'tree' than people who don't dream of trees, or than people who are awake for the same amount of time thinking of trees.

WHAT ARE THE POTENTIAL FUTURE APPLICATIONS?

AH: I'm interested in nightmare treatment. I think that would be really badass, if we can do some dream guiding with people who have a lot of anxiety about falling asleep.

So, PTSD is the extreme example, but there are lots of people who don't have PTSD who have nightmares they want to deal with. And for those, sleep onset specifically is the worst part of the night because they're terrified to go to sleep. It takes them a long time to go to sleep and when they do go to sleep they wake up in a nightmare, so they have to go through sleep onset again. Ameliorating the sleep onset, and that anxiety, I think, would be really a lovely goal.

ADAM HAAR HOROWITZ
Adam is a research assistant at MIT Media Lab's Fluid Interface Group.

TOMÁS VEGA
Tomás was a research assistant at MIT Media Lab's Fluid Interface Group when the study was carried out, to find out whether there are conscious behavior, like coding, embedded in these subconscious/conscious interactions.

Klettsvik Bay on the Icelandic island of Heimaey

CONSERVATION

Captive beluga whales rehomed in open-water sanctuary

The two whales, named Little White and Little Grey, have completed their 9,500km journey after almost a decade in captivity

Two beluga whales have been rehomed by British charity the Sea Life Trust, to the world's first open-water sanctuary for beluga whales, located in Iceland's Klettsvik Bay.

Captured from Arctic waters off the coast of Russia when they were around a year old, the pair were sold to Shanghai's Changfeng Ocean World aquarium where they lived in an enclosed indoor space. Now, after nine years of being on show and performing tricks, their new home is a specially designed 32,000m^2, nine-metre-deep seawater sanctuary. The bay is enclosed by netting, while pontoons provide access for the care team.

There are around 300 beluga whales in captivity, many of them in unsuitable conditions. Moving them into sanctuaries can help them live richer lives, says the Sea Life Trust.

1

2

3

4

PRESS ASSOCIATION X4

1. The whales will spend several weeks in a netted-off care pool to help them to acclimatise to their new home. Due to the length of time spent in captivity, they would be unable to survive in the open ocean.

2. Little White and Little Grey are thought to be about 10 years old. Beluga whales can live to well into their 40s, so they could be at the sanctuary for decades to come.

3. The whales weigh in at around 900kg each, making the use of specialist lifting equipment such as hoists and cranes essential for moving them around.

4. The Klettsvik Bay sanctuary has space for about 10 belugas, but the team say they have no plans to find playmates for Little White and Little Grey for the foreseeable future. Instead, they want to concentrate on making the pair comfortable in their new home as soon as possible.

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REALITY CHECK

SCIENCE BEHIND THE HEADLINES

Face coverings | Competitive eating | COVID-19 vaccine trials

REVIEW

FACE MASKS: ARE THEY CHANGING HOW WE BEHAVE?

Wearing face masks could affect how we communicate

"In a pre-pandemic world, you'd see masks used in situations that suggest risk or danger, like handling hazardous substances or investigating a crime scene"

BBC

Visit the BBC's Reality Check *website at* ***bit.ly/reality_check_*** *or follow them on Twitter* ***@BBCRealityCheck***

One of the more obvious societal changes brought about by the COVID-19 pandemic is that it's now far more common for people to wear masks in public. This is good: the masks are helping to limit the spread of COVID-19. But as masks become commonplace, it's interesting to consider how they affect our interaction.

The human face plays an important role in much of our communication and interaction. We've even evolved dedicated brain regions for recognising faces. So, obscuring half of it won't go unnoticed. As some have pointed out, until recently, covering the face was generally treated with much suspicion, something often used by unscrupulous types to stir up ideologically-useful Islamophobia by condemning the wearing of niqābs.

GETTY IMAGES, ALAMY

BELOW Making small talk at the salon may become more difficult

Consider our perception of masks in the pre-pandemic world. You'd invariably see them used in situations that suggest risk or danger, like when people handle hazardous materials or waste, or investigate crime scenes. Television portrayals of muggers and violent criminals typically show them wearing a mask. Even surgeons and dentists, regular mask-wearers, while undeniably there to help people, mean masks are associated with poor health, body violation, and other things we don't like.

One potential outcome of this is that we all become more wary, more attentive to dangers. A constant presence of threat cues in our environment has marked effects on our attention and thinking. It could lead to people being more anxious, less engaged, and slower to respond to what's going on around them, even if it's important, because masks mean that part of our brain is always preoccupied.

On the other hand, seeing masks everywhere could make people *less* worried. It suggests things are under control, that protection is present, that danger is minimised. Of course, this can have downsides, too. Studies into bike helmets, another head-covering garment intended to reduce hazards to health, have shown that wearing them can often make people take *more* risks.

Would regular mask-wearing lead to people taking the risks of COVID-19 less seriously? That's far from guaranteed. Masks are a very different thing to helmets, and are perceived differently, but it's something to keep an eye on.

One obvious concern about masks is the effect they have on communication. As stated, our faces play a big role in how we communicate, and masks undeniably obscure it. This causes issues for both the communicator and the communicatee.

We could end up with people displaying some mild version of the disinhibition effect, usually seen online when people can communicate anonymously, and subsequently ➤

“Not being able to read people’s facial expressions seems to make us more wary, more suspicious”

show a lack of restraint and concern for who they’re talking to, which is why the internet can seem so hostile.

Admittedly, it’s somewhat far-fetched to expect people to suddenly abandon all social norms when talking to someone, just because they can’t see part of the person’s face. But then, studies into people with facial paralysis show that others do tend to perceive them more negatively. Not being able to read people’s facial expressions seems to make us more wary, more suspicious.

Interestingly, the same studies reveal that those with facial paralysis tend to compensate for their inability to produce facial expressions by exaggerating their voice and their body language, conveying their emotions with more exuberant arm movements, larger gestures, more emphasis on words, and so on. And this does indeed make others perceive them more positively.

It’s interesting to see whether this will occur on a larger social scale, and we end up displaying emotions more with our bodies, when our faces are covered. Particularly in Britain, a country where people often pride themselves on being reserved and aloof.

At the end of the day, humans are an incredibly interactive species, and it’ll take more than a virus and masks to stop us communicating. How we end up overcoming these obstacles remains to be seen.

by **DR DEAN BURNETT**
(@garwboy)
Dean is a neuroscientist, author, blogger, occasional comedian and all-round ‘science guy’. His bestselling book The Happy Brain *(£12.99, Guardian Faber), is out now.*

ANALYSIS

EATING CONTESTS: IS THERE A LIMIT TO HOW MUCH YOU CAN CONSUME IN ONE GO?

This summer, the world record for the ‘sport’ of hotdog speed-eating was broken for the third time in five years. Are we approaching peak performance?

Who would you pick as the world’s greatest-ever athlete? Usain Bolt, Serena Williams, Muhammad Ali, Tiger Woods, Roger Federer, or Michael Phelps? No doubt they have all dominated their sports at various times, but what about Joey Chestnut? Most people have probably never heard of him, but for the two million viewers who tune in to what must be the weirdest event of the US sporting calendar, Joey ‘Jaws’ Chestnut is a bona fide legend.

Chestnut is the undisputed champion of competitive eating and has utterly dominated the hundred-year-old ‘Nathan’s Famous Fourth of July International Hot Dog Eating Contest’ – an event that has become the must-see

ABOVE Fans cheer at the 2019 Nathan's Famous International Hot Dog Eating Contest

GETTY IMAGES

event for fans of Major League Eating everywhere (yes, seriously). Every summer, frankfurter-guzzling heavyweights fly in from all corners of the globe to stuff themselves silly for 10 minutes in front of a crowd of 40,000 screaming spectators, with each competitor hoping to return home with the victor's Mustard Belt. Chestnut, a 104kg (230lb) food hoover has been toppled only once since 2007. He has broken more world records than any other competitor, and in this year's low-key socially distanced event, he broke his own world record (again) by ingesting a gut-busting 75 hotdogs (buns included) in 10 minutes – a staggering 33 more than the next best competitor.

BINGE TO WIN

You might scoff at the idea that this grotesque gladiatorial spectacle could be considered the world's fastest-growing 'sport', but this rapidly ballooning industry has just birthed some serious and thought-provoking science research. An investigation recently published in the respected academic journal *Biology Letters*, has deduced that the 10-minute record will never exceed 84 hotdogs – this is the absolute human limit. According to the paper's author, Dr James Smoliga, not even Chestnut could eat any more.

This is undoubtedly click-bait science of the highest order, hitting the tabloid headlines, and it carries the distinct whiff of fast food industry-funding. Rest easy, though, any worries that Big Hotdog are taking a bite out of independent science research are unfounded.

Chatting with the slim-framed Smoliga one lunchtime, he explained to me that the annual hotdog-eating contest has been a "guilty pleasure" for him since the 1990s. He told me that this investigation was a natural evolution from his previous track-and-field performance research: "It just dawned on me: I bet the hotdog competition follows the same pattern [of performance seen in other sports]". Taking the baton on from other scholars who have used statistics and high-level mathematics to predict the limits of human physical abilities – such as the theory that the marathon will never be run in less than 1:58:05 – Smoliga plugged in 39 years' worth of Hotdog Eating Contest data to these sophisticated mathematical models. Plotting the results on a graph, it was clear, he says, that competitive-eating abilities have improved on a trajectory that almost exactly mirrors that of other sports. Throughout the 1980s, hotdog-eating records improved only slightly year-on-year, equivalent to conventional sports before they turned professional. Victors of the burgeoning event were mostly a "bunch of objectively obese men", Smoliga explained, capable of forcing down about one hotdog per minute. This all changed in 2001 when highly trained Japanese eaters suddenly burst onto the scene, rapidly devouring the competition. Leading the pack was Takeru Kobayashi, who made light work of the competition, doubling the then world record from 25 to 50 hotdogs on his first appearance.

Ding-dong battles between Kobayashi and America's best eaters saw a flood of sponsorship money and the curious competition quickly turned professional. With greater incentives comes greater participation, improved training techniques and strategy. The early 2000s in competitive eating parallel the huge gains made in athletics in the 1970s and 1980s.

NEXT GENERATION

The new generation of competitive eaters train themselves hard. Realising that excess fat stifles the stomach's ability to rapidly inflate, the competitors keep themselves trim, and train their bodies to tolerate ever-increasing amounts of food without gagging. By regularly slurping vast amounts of soup, a competitive eater can progressively stretch their stomach, much like how ear lobes can be stretched to extraordinary proportions with earrings that steadily increase in size.

ABOVE Joey Chestnut defends his title at 2019's Nathan's Famous International Hot Dog Eating Contest

Smoliga's analysis deduced that the absolute maximal 'active consumption rate' (ACR) – the amount of fresh matter than can be consumed in a given time – would be 832g per minute.

Not content to leave it there, Smoliga went on to compare our food-gobbling abilities with other animals' scoffing skills. "I thought that this is going to be a really interesting topic to write about and to explore the underlying science," says Smoliga. In the league table of mega munchers, *Homo sapiens* are on par with grizzly bears, faster than coyotes, but slower than wolves (which can consume over a kilogram of meat per minute).

Top competitive eaters' abilities are astonishing – Chestnut wolfed down nearly 7.5 kilograms of food (22,000 calories – enough for 10 days) in 10 minutes in his 2020 triumph. And while the science may show that competitive eating serves as a curious thought experiment for understanding human abilities, it doesn't offer an easy answer on whether you consider this potentially dangerous discipline to be a true sport. "I'm not sure I want to be on the record either way," Smoliga tells me, "but if I had to choose, I would call it a sport – if bass fishing is a sport, then this is a sport – although I wouldn't recommend it!"

by **DR STUART FARRIMOND**
(@RealDoctorStu)
Stuart is a science writer, educator, presenter and tutor in food science at Cambridge University. His award-winning book The Science Of Cooking *(£20, Dorling Kindersley), is out now.*

ANALYSIS

COVID-19: SHOULD WE INFECT PEOPLE WITH IT?

A vaccine may be available sooner if volunteers are deliberately infected. But is it ethical?

The race for a COVID-19 vaccine is hotting up. There are currently over 150 candidate vaccines in development around the world, with around 30 being tested on humans.

But for some scientists, the progress isn't fast enough. There are growing calls for so-called 'human challenge studies', which would deliberately infect volunteers with the coronavirus SARS-CoV-2, with the aim of speeding up vaccine development by, according to one paper, as much as several months, potentially saving thousands of lives.

This would be a big ethical leap from current vaccine trials. Currently, a candidate COVID-19 vaccine goes through three phased trials. In the final trial (phase III), up to 10,000 volunteers are given either the candidate vaccine or a placebo. The volunteers then go about their daily lives, and the scientists wait to see who gets infected, and who doesn't. If the vaccine works, the scientists should see significantly fewer COVID-19 cases in the vaccine group than in the placebo group.

The downside of this approach is that it takes time for volunteers to become infected, especially in countries with falling case numbers. Human challenge studies could potentially speed up the process by giving the candidate vaccine to a much smaller group of volunteers, and then, once the vaccine has triggered an immune response, directly infecting them with the virus. The scientists would monitor how the volunteers respond to the virus, gathering real-time data on the vaccine's effectiveness.

Of course, infecting someone with COVID-19 comes with risks: mild illness, severe illness or even death. Even so, at the time of writing, over 32,000 people have registered their interest in volunteering for COVID-19 challenge studies, via 1Day Sooner. In July, this advocacy group (co-founded by Josh Morrison, who also set up an advocacy group for kidney transplantation), revealed that it was working with Oxford University's Jenner Institute to manufacture

GETTY IMAGES X2

ABOVE A volunteer takes part in a COVID-19 vaccine trial in America

the virus ready for challenge studies.

"We see considerable potential in the use of human challenge studies to accelerate COVID-19 vaccine development, downselect and help validate the best candidate vaccines, and optimise vaccination approaches," said Prof Adrian Hill, director of the Jenner Institute, which is also developing one of the leading candidate vaccines. Hill is also one of over 100 signees on an open letter in support of challenge studies that 1Day Sooner sent to Dr Francis Collins, director of the US National Institutes of Health.

1Day Sooner makes it clear that it supports *ethical* challenge studies. In May, a working group at the World Health Organization (WHO) published its ethical guidelines for such studies. To minimise risk, the selected volunteers would need to be relatively young adults. (According to data from China, the risk of dying if infected by COVID-19 is around one in 3,200 for people aged 20 to 29, compared to around one in 150 for the general population.) The volunteers should also have no underlying health conditions, and they'd need to be isolated throughout the study, and carefully monitored both during and afterwards.

The ethical argument for challenge studies comes down to whether the potential benefits to society can justify the risks to individuals, says Prof Seema Shah, an expert in medical ethics at Northwestern University in Illinois, US, who is part of the WHO's working group. For instance, she questions whether challenge studies would be ready in time to significantly boost the development of the first COVID-19 vaccine, given that standard trials are already moving so rapidly.

"It takes time to get challenge studies approved by research ethics committees," says Shah. "And you also need to figure out how to infect people in the right way. You need to develop strains of the virus that will infect everybody [in the challenge study] but won't make anyone too sick. That can all take many months."

Shah says that challenge studies might be more useful in developing an improved vaccine. "A first vaccine might be imperfect – it might not work in everyone, for example, or it might be expensive. Challenge studies could be a way to quickly test the effectiveness of alternative vaccines."

There's also the question of whether challenge studies should wait until there's a failsafe treatment available for COVID-19, or until scientists know more about the long-term effects of the virus. "Past challenge studies [with other diseases] have been done either when there's a cure available, or when we know a lot about the disease," says Shah. "[Challenge studies with] the coronavirus would go a step beyond what's been permitted to date."

Experts are split, says Shah, on how soon we should embark on a challenge study. But she says that it's important to lay the ethical and practical groundwork, so that these studies are ready to go ahead if ethics committees decide that the benefits outweigh the risks.

"We need to have a public conversation about this, and there needs to be transparency from those planning the studies," says Shah. "Challenge studies are a powerful tool in the arsenal, but they need to be used carefully." **SF**

"The ethical argument comes down to whether potential benefits to society can justify risks to individuals"

by **JAMES LLOYD**
James is the staff writer at BBC Science Focus.

SFP354

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Hello! It's our smart doorbell round-up p36

INNOVATIONS

PREPARE YOURSELF FOR TOMORROW

With its smiley face and retro interior, the Honda-e doesn't stray far from the much-loved original concept (inset)

OTHER AWESOME EVS

Ford Mustang Mach-E 1400

Ford's racing division's new electric car, the Mustang Mach-E, is a 1,400bhp monster, proving that it can be just as thrilling as the company's fossil-fuel-powered racing cars.

Lotus Evija

Okay, we'll ignore the name, since Lotus says this hyper car will offer 1,972bhp. Production started this year, so expect to see one parked outside your local Tesco Express soon.

Rivan R1T

Rivian wants to "keep the world adventurous" with its electric pick-up truck. When it arrives, it'll offer 644km (400 miles) of range and around 750bhp plugged into all four wheels.

CARS

Not just a pretty face....

The Honda-e is the most anticipated car of the year, and it's all-electric. Daniel Bennett finds out if it lives up to the hype...

What's the deal?

When Honda revealed its Urban Concept car back in 2017, it was an instant hit. The design was an impeccable example of retro-futurism, with end-to-end touchscreens mounted onto faux wood in front of old-fashioned bench seats. By some miracle, that original design survived its journey to the real world and we now have the rather cute Honda-e, Honda's first proper electric car. It costs £26,160-£28,660, including the government grant.

How is it different from other electric vehicles (EVs)?

Let's get this out of the way: the range is between 204 and 219km (127 to 136 miles), depending on the model. If you've experienced range anxiety, that figure will put you on edge. But with the average car journey clocking in at 12.5km (7.8 miles), there ought to be buyers for whom this won't be a dealbreaker, especially those families who run two cars.

"THE HONDA-E IS LIGHTNING QUICK, BOASTING A MINUTE TURNING CIRCLE AND A BRILLIANT TECH PACKAGE"

In theory, Honda has saved money and weight on the battery to improve the car elsewhere. In practice, it's a trade-off that's plain to see. The Honda-e is lightning quick, boasts a minute turning circle and has a brilliant tech package. It's the perfect tool for traversing jammed city centres.

What makes it so good?

Dozens of small but significant features add up to something special. Side mirrors have been replaced with cameras connected to small displays next to the car door. The infotainment system is split into two: one side for the passenger, one for the driver, so you can choose your tunes without disrupting the sat-nav. The displays are fully customisable and there's a virtual assistant on-board. Rear-wheel drive and an electric drivetrain means the front wheels are free to turn at a 50° angle, allowing for a 4.3-metre turning circle – that's comparable to a London black cab. Pair that with the car's 50:50 weight distribution and you have something that's not far off a hot hatch, only the suspension's been left spongy to soak up the potholes and speed bumps that litter city centres. Parking is a breeze, but if you need help there's an autonomous system that'll do it for you. If you want to loan the car out to the kids, share a key via the Honda app, and geofence off an area to alert you if they go somewhere they shouldn't.

Why should I care?

It seems likely that cities will impose more restrictions on vehicles to mitigate air pollution levels. Commuters who can't rely on public transport will need viable options. So we need desirable electric cars to grow the industry. Take a look at the iPhone. While Apple's devices don't always have the longest battery life or the most powerful equipment, it's the way their products feel that draws customers to them. And ultimately, better EVs mean cleaner, quieter roads for the rest of us.

NEWSPRESS

BUYER'S GUIDE

SMART DOORBELLS

Want to start converting your house into a smart home? An internet-connected doorbell is the perfect 'entry-level' product to start. ***Jennifer Tuohy*** *gives us the lowdown...*

Smart doorbells use a camera, speaker, microphone, motion sensor and internet connection to detect visitors and activity on your doorstep, meaning you can stay in touch with your home via your smartphone, wherever you are.

The safety and security benefits are obvious. There's no need to answer the door without knowing who's there, you can protect packages while you're away, you can direct delivery drivers, and see who got back home and when. And, during this time of social distancing, a smart doorbell is an essential tool for the vulnerable and elderly.

What you need to know

Do you already have a doorbell?

If you have an existing, working doorbell, the chances are you can install a wired smart doorbell. A wired-in buzzer is a better bet than a battery-powered one, because you don't need to worry about charging it and it will ring your existing doorbell chime.

Wired-in doorbells are also more reliable for capturing all the action on your doorstep when compared to their wire-free siblings, which have to 'wake-up' before they start recording – resulting in the common 'back of the head problem' (when all you get is a clip of someone walking away). The downside is the wired-in doorbells have a more complicated installation process, which you might need to call an electrician to carry out.

Video quality matters

You're likely tired of hearing about how many megapixels the newest smartphone camera has. But when it comes to security camera footage, quality matters. You want at least 1080p HD resolution, or you'll be left with a barely visible recording. Super HD (1440p and higher, also known as 2K) is a bonus and gets you sharper, clearer images. Digital zoom, 6x or higher, is also something to consider, especially if you might want to zoom in on a licence plate number as it sideswipes your parked car. And unless you have an always-lit front porch, then night vision is a must.

Don't fall for cloud storage subscriptions

If you just want to see who's at your door when they're there, and bark instructions at them from behind the safety of your smartphone screen, then you don't need to pay a monthly subscription fee. On the other hand, if you like the idea of literal 'visual voicemail' for your house, pony up a few quid a month and you'll get recordings of anyone who comes to your front door (whether they press the button or not).

Smart doorbell jargon buster

As you research the best options for making your front door smart, you'll come across some of these phrases:

LATENCY The amount of time between the moment a frame is captured and when that frame is displayed on the receiving screen. Long latency is an issue with most doorbells and means you'll have to wait a few seconds to see your visitor and also for them to hear you.

LIVE VIEW Watching a live stream of video footage. All video doorbells offer this so you can check in on your doorstep, even if you didn't get a motion alert.

TWO-WAY AUDIO The ability to hear audio from video footage and transmit audio to the same stream. It requires your doorbell to have both speaker and microphone.

CLOUD STORAGE An online space where recorded video is stored, so it can be accessed from anywhere you have an internet connection.

ASPECT RATIO The dimension of the video footage you will see through your doorbell's camera. A wider aspect ratio such as 16:9 will show you more side-to-side but may cut off faces and feet. A squarer ratio such as 4:3 or 1:1 offers a more head-to-toe view.

Consider smart features

There are various features that cut down on how many times you need to pull your phone out of your pocket to check on your front door. These include customisable motion zones to cut out a busy street, and smart notifications that only alert you if there are people or packages on your porch. Some of these require a subscription.

Do you need assistance?

If you have a smart speaker or screen, look out for a doorbell that works with your choice of virtual assistant. Both Amazon Alexa and Google Assistant speakers are able to broadcast a message when your doorbell is pressed, and the smart screens act as a video intercom so you can see and speak to your visitor without having to pull out your phone. There are currently no smart doorbells that work with Apple's HomeKit.

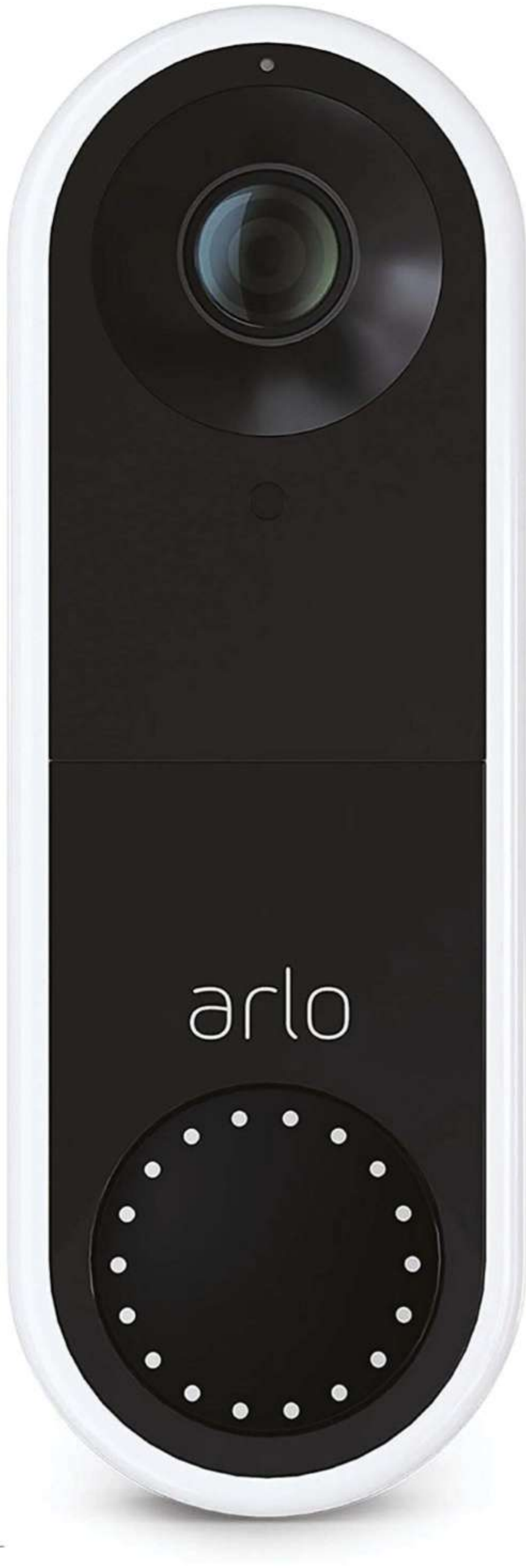
Make sure you have decent Wi-Fi

Streaming video from your doorbell takes a fair bit of bandwidth and if you don't have strong Wi-Fi by your front door, you'll struggle to get a good connection and reliable images. Check how strong your Wi-Fi is there before buying, and if it's weak consider installing a Wi-Fi extender.

Don't film your neighbours

A video doorbell records audio and video, so falls under CCTV regulations. As it's likely to see spaces outside your property – such as public streets or a neighbour's front path – any recorded footage falls under General Data Protection Regulation. If you're only using live streaming it's not a problem, but if you are recording video, use the included stickers that come with your smart doorbell to advertise to visitors they're being recorded. Audio is more problematic in terms of privacy, but some companies – such as Ring – let you disable it completely if you're worried.

The options...



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1. Our choice: Arlo Video Doorbell

Offering a good balance between price, premium features, and usability, Arlo's Video Doorbell is our top choice if you want a high-quality, reliable device.

Its standout feature – telling the difference between people, animals, vehicles, and packages, and only sending you the notifications you want – means you don't get an alert every time a strong breeze sends a plastic bag down the street.

Being able to create motion zones – so you get alerted only when someone (or the neighbour's cat) is in them – and the option to turn off all alerts when you are home (using the location of your phone to figure this out) ensures a smart doorbell doesn't become just another electronic annoyance but a useful security tool.

Along with some of the best-quality video we tested and a square video shape that shows you more of your doorstep, we like that it has a built-in siren you can set off from the app if you spot someone suspicious.

It also has an answering machine. While no one left us a message – possibly because most people aren't used to talking to a doorbell – we can see potential here as smart doorbells gain popularity.

PRICE: £179.99 | **SUBSCRIPTION:** £2.50/month | **RESOLUTION:** 1536p x 1536p | **POWER SOURCE:** Wired with battery backup

2. If money's no object: Google's Nest Hello

It you like the idea of your Google smart speaker announcing that "Your mother-in-law is at the front door" so you can scarper, the Hello doorbell will wow you with its smart features.

The only smart doorbell with facial recognition, the Hello just needs you to identify people once in its app and it can tell you exactly who is at your door. It will also detect packages and alert you to sounds such as a dog barking, and can automatically shut off recording when you're home so you don't have hours of video of your comings and goings.

You do pay a pretty penny for these benefits however, but you get top-notch video quality and 24/7 recording, making this much more effective as a true security camera than any of the competition. The downside is that all that video will eat through any bandwidth cap you might have, although you can adjust the quality of the stream to counter this. It also doesn't play as well with Alexa, if that's your smart speaker of choice.

PRICE: £229 | **SUBSCRIPTION:** £5/month | **RESOLUTION:** 1600p x 1200p | **POWER SOURCE:** Wired

3. Best for privacy: Eufy Video Doorbell 2K

We cannot tell a lie: this one almost made the top spot. Eufy's newest doorknocker has the highest quality resolution of any doorbell on the market today and delivers a beautiful, crisp, clear picture. It works on a battery that it says will last 180 days (in our testing it was at 90 per cent after two weeks), so you can stick it anywhere you need to on your front door, making installation really simple (it can also be hardwired).

The killer feature is that it doesn't rely on the cloud at all. Your video stays in your home on Eufy's included HomeBase (which you plug into your router and also acts as an indoor chime). This means no subscription costs and no chance of anyone getting hold of your video from a cloud server.

But because it's battery-powered (and even when wired) it suffers from the back-of-the head problem that plagues all similarly powered doorbells: it doesn't always wake up in time to catch that person at your door before they walk away.

PRICE: £199.99 | **SUBSCRIPTION:** No monthly fee | **RESOLUTION:** 2560p x 1920p | **POWER SOURCE:** Wired or battery

4. If you're on a budget: Ring Video Doorbell

The original may not be the best, but for £89 you can't go too far wrong with the Ring Video Doorbell. A basic buzzer that doesn't require wires (but can use them if you have them), this does the job you need, but you'll have to take it down and charge it every couple of months – depending on whether or not your front door is as busy as Heathrow at Christmas.

There are fewer features at this price, but if you pay for the subscription it can alert you only when a person approaches, not every tree branch. We found this wasn't always reliable – sometimes it thought a rocking chair was a person and other times it entirely missed actual people – but it did help cut down on alert fatigue.

All of Ring's doorbells work with Alexa speakers and smart screens, and connect automatically to announce "someone is at the door" or show a live view. They also all have a wide, 16:9 aspect ratio – this is good for seeing the action as it approaches from either side, but not so great for keeping an eye on packages under the camera.

Ring is the only doorbell with privacy zones, which you can draw in so you're not watching your neighbour's house – but there's no depth of field so everything in that space is blacked out. If you just want to know when someone is ringing your door and get to chat with them, and you use Alexa, then this is a great, entry-level option.

PRICE: £89 | **SUBSCRIPTION:** £2.50/month | **RESOLUTION:** 1080p | **POWER SOURCE:** Wired or battery

THE SEE-THROUGH ZOO

WELCOME TO NATURE'S MENAGERIE OF TRANSPARENCY

WORDS: BEN HOARE

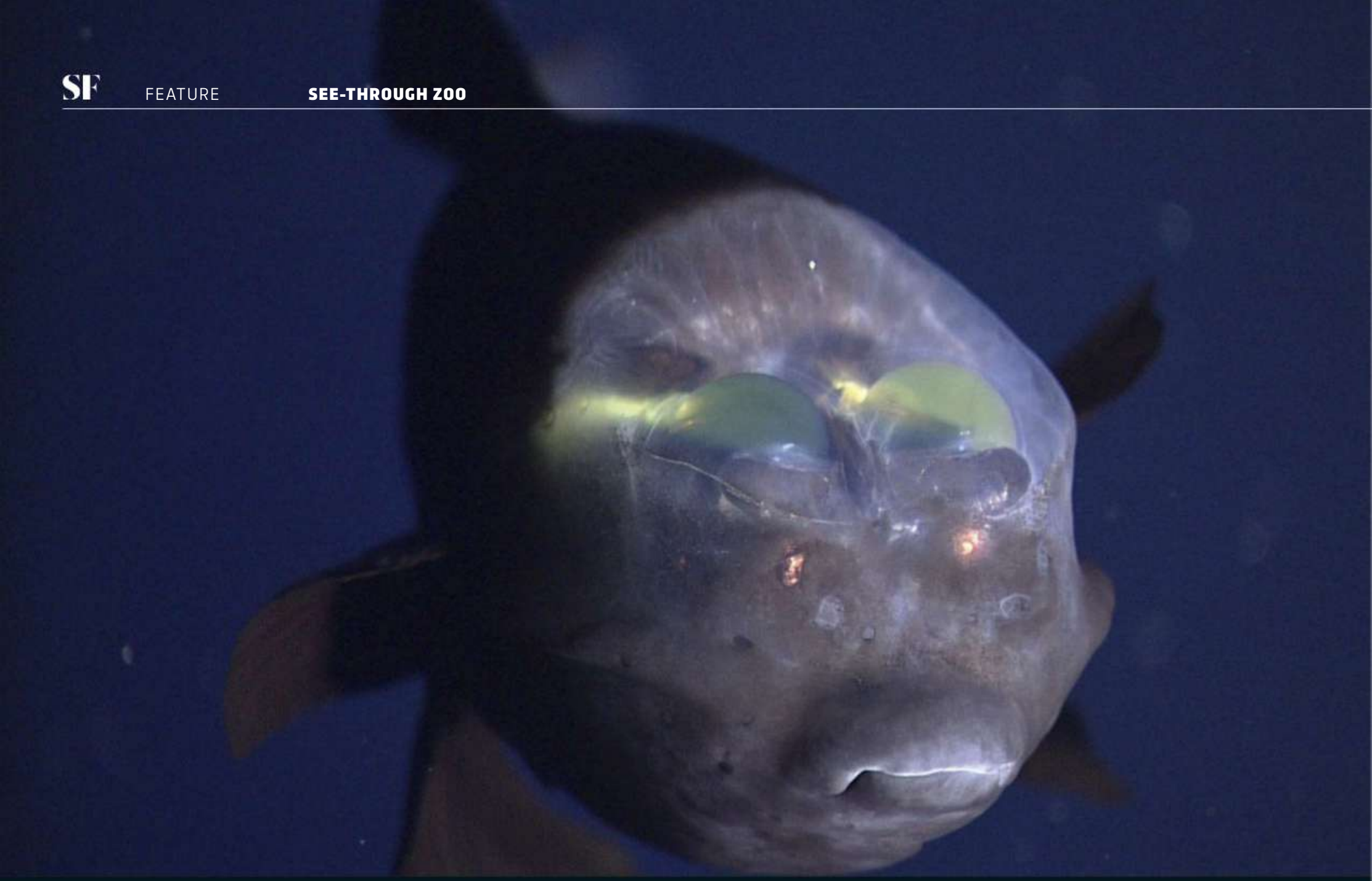
THAT TAKES GUTS

GLASS FROG

Tropical forests are teeming with predators for whom frogs are top of the menu, so these amphibians have understandably evolved some nifty defences. Glass frogs, which inhabit the humid cloud forests of South and Central America, rely on a novel form of camouflage: they bare all, or *almost* all. As this studio photo of *Hyalinobatrachium aureoguttatum* shows, their see-through skin offers up an eyeful of beating heart, blood vessels, bones and digestive tract.

But why display your innards? After all, predators can still see you. A recent study revealed the secret to their curious camouflage, and it lies not so much in their body, but their legs. As the most translucent part of the animals, their legs match the brightness of the background foliage. By blending in, the disappearing phantom limbs help to hide the true outline of these freakish frogs.

PETE OXFORD/MINDEN/NATUREPL.COM



THE EYES HAVE IT ↑

PACIFIC BARRELEYE FISH

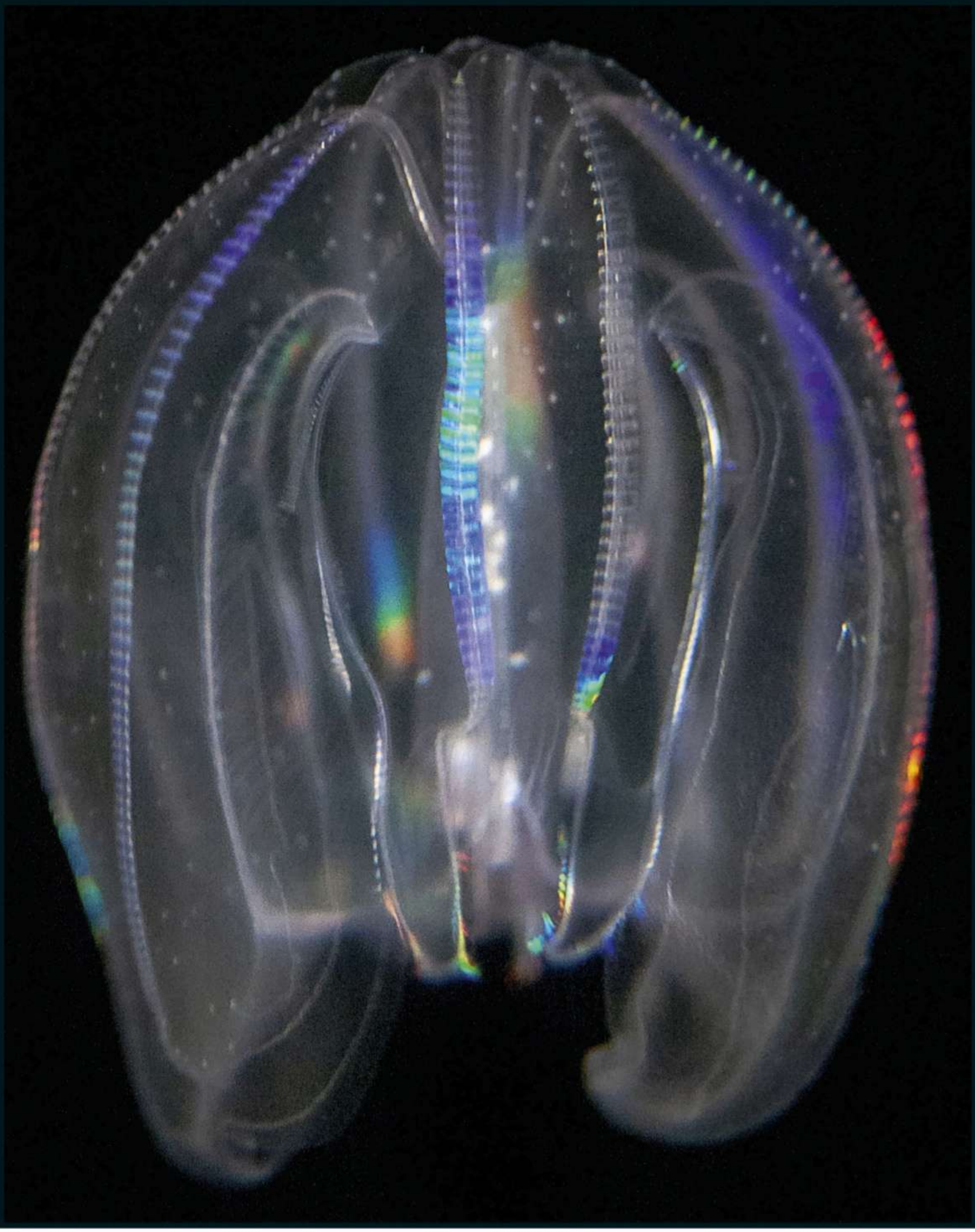
In 2004, a remotely operated vehicle (ROV) deployed at sea by researchers from Monterey Bay Aquarium Research Institute (MBARI) filmed some extraordinary video that made headlines around the world. While exploring at a depth of 600m off the coast of California, the robo-sub captured the first footage of a living Pacific barreleye or spookfish (*Macropinna microstoma*). Previously, the googly-eyed, deep-sea fish had only ever been found dead. Those specimens had all lost the transparent 'hood' that marine biologist Dr Helen Scales, author of *Eye Of The Shoal*, calls "a clear bubble like an astronaut's helmet". Thanks to the video – a still from which appears here – scientists worked out that the barreleye's telescopic, tubular eyes can swivel under their protective visor, enabling the fish to peer up, forwards or down. "The ocean is a near-limitless 3D environment," says Scales, "so there's a selective pressure for the ability to scan above and below. Plenty more fish like this are probably waiting be discovered."

GOING WITH THE FLOW →

SEA WALNUT

'Brainless but beautiful' is a pretty fair description of the Atlantic sea walnut (*Mnemiopsis leidyi*). Up to 97 per cent water and super-fragile (were we to handle it), the creature lacks a single decision-making structure and instead gets by with a much simpler, decentralised neural system known as a 'nerve net'. It is among countless more-or-less transparent animals drifting through the surface waters of the world's oceans, such as comb jellies (the group to which sea walnuts belong), true jellyfish, octopuses, squid and marine worms. Like other comb jellies, the sea walnut moves itself forward with long, hair-like threads called combs. When bright artificial light from a sub or diver's strobe flash hits one of them, it pulsates with rainbow colours like an underwater laser show. "Being blobby makes sense for the sea walnut and other plankton, since jelly is neutrally buoyant [it stays at the same depth without rising or sinking] and cheap to make – it's essentially just collagen and water," says Scales.

2015 MBARI, BLUEPLANETARCHIVE / MASA USHIODA



WINDOWS ON THE WORLD

GLASSWING BUTTERFLY

If a glasswing butterfly (*Greta oto*) landed on this paragraph and opened its 6cm wingspan, the text would still be perfectly readable. In their native Central America, these stunning insects are commonly known as 'espejitos', meaning 'little mirrors', although their wings are quite unlike mirrors and reflect hardly any light at all. That's because the clear portions are scaleless and possess minuscule waxy structures called nanopillars, which are randomly arranged across the wing surface to serve as an anti-reflective coating. This adaptation may make it harder for predators to spot the butterfly, although this hasn't yet been proven. "Butterfly wings never cease to amaze me," says entomologist and BBC presenter Dr Ross Piper. "They do all sorts of amazing stuff. They've become important not just in visual displays, including camouflage and mimicry, but in thermoregulation and the release of pheromones."

ALAMY

VANISHING ACT ↓

GHOST SHRIMP

Many shrimps worldwide have exoskeletons that are to varying degrees see-through. We can gawp at their inner workings, watch their last meal being digested and – in females – see bundles of eggs developing. In the watery realm that these crustaceans inhabit, transparency is a highly effective vanishing act, enabling them to merge with their background, whether open water, seabed or reef. Transparency is relatively straightforward for an aquatic species such as a shrimp, since the refractive index of water is far higher than that of air, and conveniently close to that of the animals' exoskeleton and other tissues. There's little or no difference in how light passes through water and their bodies, so they disappear. Some tiny marine shrimps have evolved an intimate relationship with sponges, clams and anemones, seldom straying from their host. The ghost shrimp pictured below is resting on its glass sponge home.

HIDING IN PLAIN SIGHT ↑

TORTOISE BEETLE

Roughly a quarter of the animal species identified so far are beetles, and their world-beating success is partly down to uniquely versatile body armour. Beetles own a pair of tough wing-cases, or elytra, that snap shut and act as swing doors for the hind wings underneath. In tortoise beetles, which can look a bit like tiny versions of their reptilian namesakes, the elytra really are special. "Tortoise beetles feed on top of leaves, leaving them vulnerable to predation," says Dr Ashleigh Whiffin, an entomologist at National Museums Scotland. "While some colour-match their elytra to host plants, in species such as *Acromis sparsa* (above) the edges are totally transparent. These areas are devoid of pigment, so the leaf below is visible, hiding the insect's telltale shape." Tortoise beetle larvae, meanwhile, have a somewhat less glamorous disguise. "They collect their faeces to use as a shield," says Whiffin. "The faecal shield is attached to a telescoping anus, so they can even move it around if attacked!"

by BEN HOARE *(@benhoarewild)*
Ben is editorial consultant at BBC Wildlife Magazine. *His latest book,* Wild City *(£12.99, Pan Macmillan), is out in October.*

SHIFTING SANDS ↓

NAMIB SAND GECKO

There are fewer see-through reptiles than amphibians. The thin, oxygen-breathing skin of frogs and salamanders naturally lends itself to becoming translucent, whereas the scales that cover lizards, snakes, turtles and crocodiles, do not. Among the reptiles, geckos are best at it. The Namib sand gecko (*Palmatogecko rangei*) melts into the dunes of its arid home in south-west Africa like a mirage, thanks to its ultra-pale, pink and yellowish scales. It ekes out a living by darting across the hot sand to catch crickets and other insects. Another name for this little lizard is the web-footed gecko, due to the unusual splayed feet that help it burrow and stop it sinking in loose sand. In 2015, a team of herpetologists hypothesised that, over time, as geckos migrated to open deserts from the forests where they originally evolved, the adhesive areas on their feet moved too, from the soles to the tips of their toes. Some desert geckos have lost these sticky pads altogether. SF

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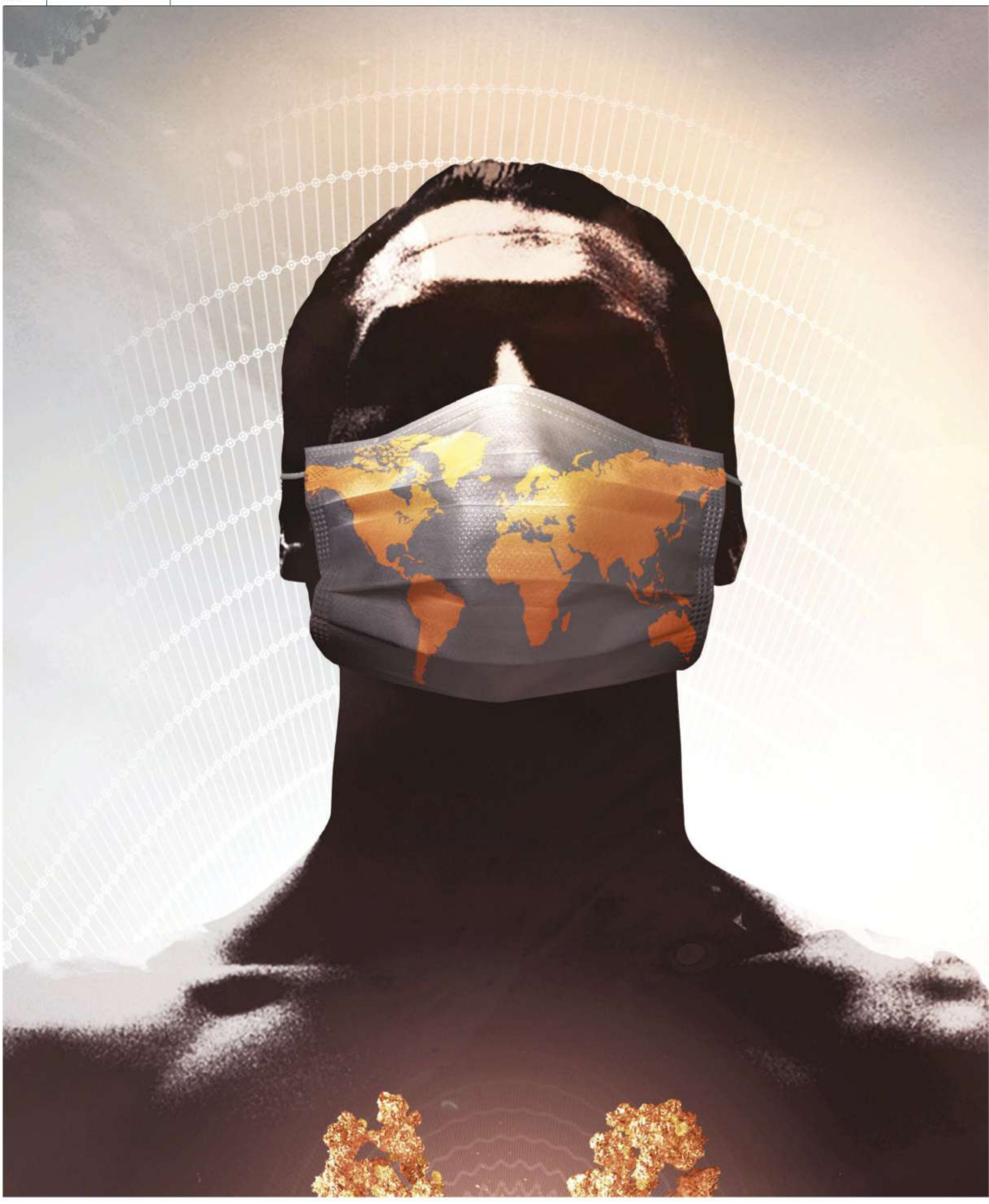

MAGICTORCH

SPECIAL REPORT

IN SEARCH OF IMMUNITY

It seems the more we learn about COVID-19, the more menacing it becomes. Why are there so many symptoms? Are some of us already immune? As scientists race towards a vaccine, we report on the latest discoveries helping us understand how our immune system handles the infection

WORDS: TOM IRELAND

WHY IS COVID-19 ABLE TO AFFECT PEOPLE SO DIFFERENTLY?

The wide range of outcomes of being infected with COVID-19 – from showing no symptoms at all, to rashes, severe respiratory illness and death – reflects the huge variation found in people's immune systems. How the immune system responds to a virus such as SARS-CoV-2 is influenced by many factors, from our genes and general health to the other pathogens we've encountered in the past.

With COVID-19, there seems to be a critical period during which the immune system either mounts a protective response, stifling the virus and slowing its spread in the body, or a dysfunctional, inflammatory response, where the body starts to attack itself.

As part of a healthy immune reaction, local white blood cells recognise the virus as foreign and release chemicals called cytokines. These molecules help direct and amplify the body's immune response, which can limit the spread of the virus and kill off infected cells. But the release of too many cytokines in a short period can start to cause collateral damage to healthy cells. In critical cases of COVID-19, the acute lung problems that are characteristic of the disease are caused by a 'cytokine storm' – a dangerous runaway overreaction of the immune system that creates even more inflammation and tissue damage than the virus.

"We know that as we age, our immune systems are not as good at clearing infections," says Dr Elizabeth Mann, an immunologist who has been following the progress of COVID-19 patients arriving at hospitals across Manchester. "Older people are also predisposed towards the types of inflammatory immune responses that cause damage in COVID-19."

As well as age, genetics also have a role to play. A recent case study that looked at four young males with severe COVID-19 found that all four had rare genetic alterations in a particular gene that helps modulate the immune response. Worryingly, in those instances when COVID-19 does cause severe illness, the effects on the regulation of the immune system can be long lasting, according to Mann.

"We're also seeing long-term abnormalities in some immune cells in the blood that persist for several months following discharge," says Mann. "This indicates that the immune system doesn't simply reset and go back to normal upon recovery."

It goes without saying that people taking certain medications that suppress their immune systems – such as those who have HIV or have recently had an organ transplant – are at risk of having a weakened or dysfunctional immune response. We also know that certain ethnic groups, such as black and Asian people, are more likely to die from COVID-19. Studies are looking at why the mortality risk is greater for people in these ethnic groups, and differential immune system reactions could be part of a spectrum of factors alongside economic, cultural and health reasons.

There is also some evidence that the 'dose' of virus you receive can be a factor in how your immune system copes with the infection. For example, a 'low dose' might involve picking up a few viral particles from a surface and then scratching your nose. But sharing a small space with an infected person who is coughing and spluttering would mean breathing in lots of viral particles, resulting in a much larger amount of viral particles entering the lungs all at once.

DOES HAVING ANTIBODIES MEAN YOU'RE IMMUNE? AND IS EVERYBODY WHO HAS RECOVERED FROM COVID-19 IMMUNE?

Once the immune system has started to fight a virus, it creates specific antibodies for that particular pathogen. These Y-shaped proteins circulate in the body and stick to anything resembling the virus, acting like a flag that tells other immune system cells to destroy it.

The presence of antibodies specific to COVID-19 in the blood has therefore been used to test if somebody has had COVID-19 and is 'immune' from getting it again. Governments around the ➤

RIGHT A coronavirus antibody test shows a negative result – no antibodies are present in the blood sample being tested

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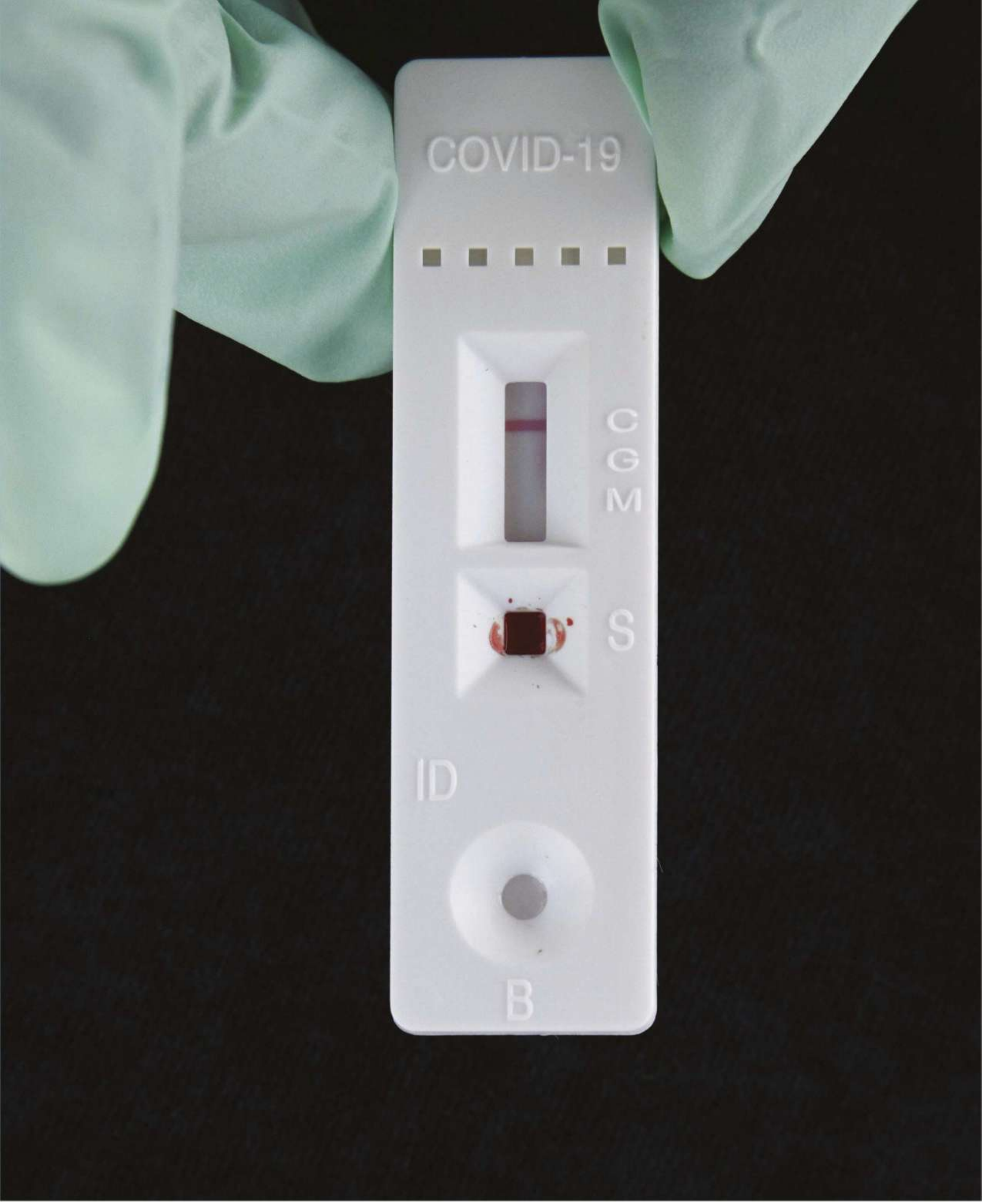
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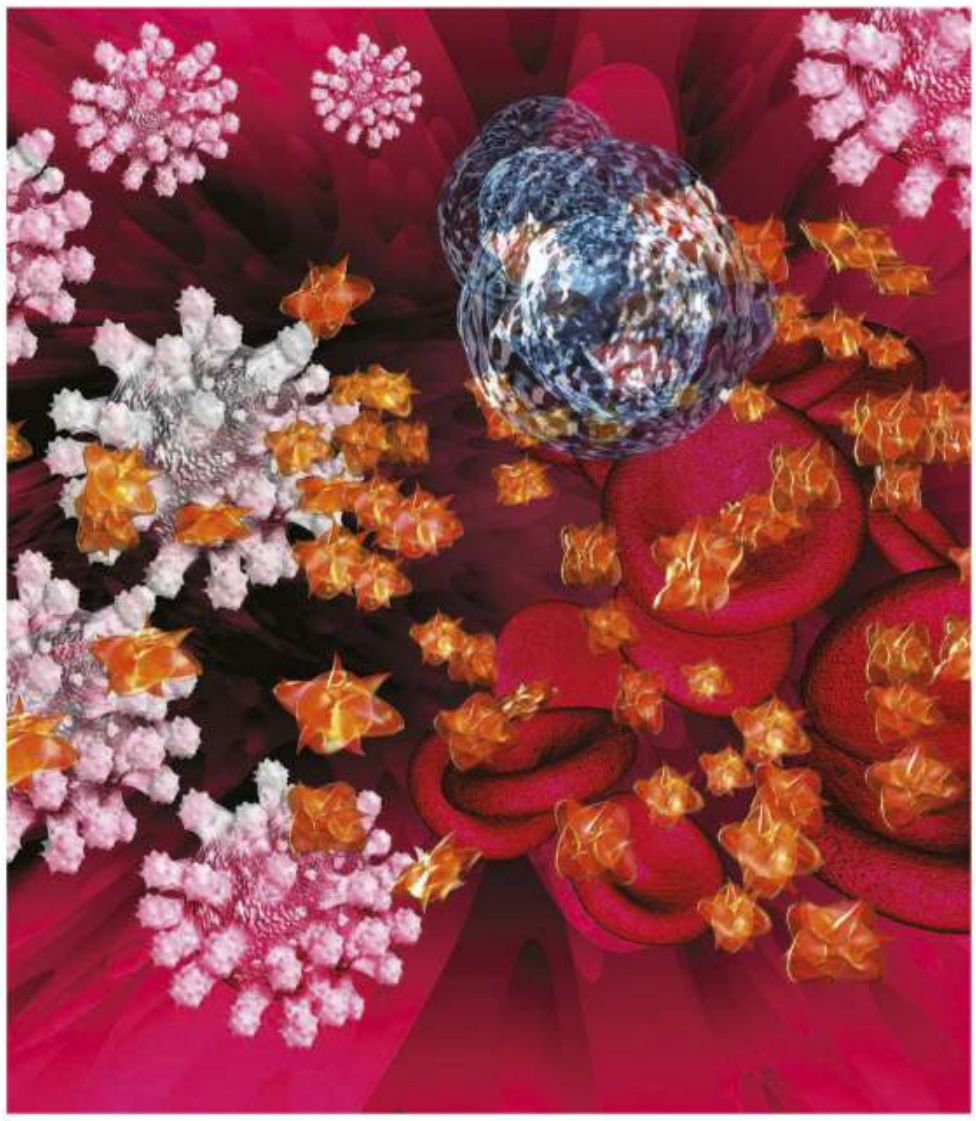

world have considered issuing people with ‘immunity certificates’ or immunity passports, including the UK, which suggested people might be given special bracelets if tests show they have COVID-19 antibodies.

Unfortunately, the messy reality of the immune system mean it isn’t that simple. Firstly, a certain percentage of the population, perhaps as many as 20 per cent, just don’t seem to make antibodies to COVID-19, making it harder to tell who has and hasn’t had it. Even when people do make antibodies, the number of those antibodies circulating in the blood can fade rapidly once that person has recovered, to the point where it may be impossible to detect any antibodies at all after a few months.

While this may seem like bad news, fluctuations in antibody levels are a normal part of immunity, says Dr Kaitlyn Sadtler, an immunologist from the USA’s National Institutes of Health. “There are viral infections that induce lifelong antibody responses, but antibody responses to respiratory viral infections often do wane. Vaccination [and immunity] is not a binary – it’s not that it 100 per cent works or it 100 per cent doesn’t work. For certain viruses, we need an initial dose and then a further one or two boosts – others might require seasonal vaccination or vaccination every few years.”

Antibodies aren’t the only way the body remembers a virus, either. “Antibody tests are quick and inexpensive, but there are also other parts of the immune system beyond antibodies that help with our immunity,” says Sadtler. Components of the immune system known as T-cells help identify cells in the body that have been infected with the virus and also help guide the production

LEFT Dr Monica Levi is one of 5,000 volunteers in Brazil who are participating in the phase III trials of the vaccine being developed by Oxford University and pharmaceutical company AstraZeneca

BOTTOM LEFT A cytokine storm is a dangerous overreaction of the immune system and can cause more tissue damage than the virus it's trying to fight

of antibodies. Even if a person has no detectable antibodies left, the T-cells will be primed to ensure the immune system responds to the threat more quickly than the first time.

DO SOME PEOPLE IN THE POPULATION ALREADY HAVE SOME RESISTANCE?

Possibly. Studies have shown that some people who haven't had COVID-19 show some innate immune 'reactivity' to proteins found in SARS-CoV-2. These people didn't have COVID-19 antibodies, but their T-cells seemed primed to respond to the virus, at least in laboratory tests. Scientists hypothesise that this could be a result of exposure to other coronaviruses, such as the common cold or the SARS virus, which circulated in 2003. Some studies suggest up to 50 per cent of people might have this underlying 'reactivity' to coronaviruses (to call it 'resistance' is probably overstating the effect), which could help them get away with milder symptoms.

Interestingly, it's believed that the common cold was once a far deadlier coronavirus, like SARS-CoV-2 is now. Having circulated for thousands of years, humans have developed a broad immune response that ensures infection with a new strain of the cold virus results in only mild symptoms. Some scientists believe that without a vaccine, COVID-19 will eventually go the same way, circulating for many years until almost everybody has some kind of broad immune system memory to it that helps fight off newer or more severe strains.

HOW DO POTENTIAL VACCINES WORK?

There are currently over 150 vaccines in trials around the world. Like any immunisation, the COVID-19 vaccines in development aim to help us develop immunity to the virus without having to go through the danger of a real infection. The 'traditional' way to do this would be to present the body with a damaged or inert version of the virus, allowing the immune system to learn how to fight it without the possibility of the virus doing any harm or replicating in the body.

As well as traditional vaccines involving a weakened or inactive version of the SARS-CoV-2 virus, a range of more modern approaches are being trialled. Some vaccines are made up of just a small part or subunit of the virus, such as the spike protein that SARS-CoV-2 uses to attach to our cells. This spike protein is completely unique to the SARS-CoV-2 virus, and so if the immune system develops a robust immune response to the protein, it should also react strongly to the real virus, which is coated in it.

Another approach is to use what are known as 'genetic' vaccines. These vaccines contain a specific sequence of DNA (or its chemical cousin, RNA) from the virus. Once this bit of genetic code is injected into the body, the body's own cells then synthesise that bit of the virus, which the body recognises as foreign, causing it to induce an immune response.

Other components can be added to such vaccines to encourage the immune system to respond, for example, special molecules that create a strong immune response known as adjuvants, or by incorporating the genetic vaccine into a different, harmless virus.

All the different types of vaccine have pros and cons. "For success in this pandemic, our best bet is to ensure we have multiple horses in the race," says Prof Trevor Drew, director of the Australian Centre for Disease Preparedness. "Live, attenuated [weakened] vaccines can take a long time to make and there's the possibility they could mutate to become more dangerous again. Subunit vaccines don't always induce robust immune responses without adjuvants. And genetic vaccines are relatively easy and inexpensive to make, but they're a new approach and there aren't actually any existing vaccines of this type [approved for use] yet."

Any vaccine must pass three strict phases of clinical trial test: checking for safety (phase I), that it works (phase II) and how well it works in large populations (phase III). Despite the best efforts of public health organisations to fast-track these trials and cut down on bureaucracy, just 20 of the potential 150 vaccines currently in development have progressed to human trials so far.

The most advanced candidate so far is being developed by the Oxford University and pharmaceutical giant AstraZeneca. Early results from human trials have been positive and there are plans already taking shape to produce over two ➤

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billion doses in the next year. The vaccine is made up of a harmless virus that can't replicate, but contains the gene to produce the SARS-CoV-2 spike protein. In trials involving around 1,000 volunteers, the vaccine provoked a T-cell response within 14 days of vaccination and an antibody response within 28 days.

"We're using replication-deficient adenoviruses because they can't spread and they're very safe," says Prof Sarah Gilbert, one of the Oxford University vaccinologists working on the vaccine. "They're also very good at inducing an immune response to the gene that you've added to them, because you're actually getting a viral infection. So when you vaccinate somebody, the adenovirus goes into cells at the injection site – it infects them. The cells react as if there's an infection and the antigen that's been produced in large quantities is the coronavirus spike protein.

"The immune cells in the body haven't seen that spike protein before. So that's what they latch on to and you get a strong immune response to it. As the adenovirus can't replicate, it's lost from the body pretty quickly, so you're left with that immune response and the memory immune response."

There are still many steps required to prove that the vaccine's effects actually prevent COVID-19 infections and that the effects last; more tests are needed to ensure it's effective and safe to use in more vulnerable groups, such as older people or pregnant women. Gilbert has been inundated with people asking when the vaccine will be ready and the truth is, it's impossible to say.

"We have to have three things: we have to prove vaccine efficacy, there has to be large amounts of vaccine made, and we need regulatory approval. We can't tell the timing on any of them very precisely."

ABOVE Red Cross volunteers in California making face masks to help prevent the spread of influenza during the pandemic of 1918

GETTY IMAGES

BEFORE A VACCINE IS AVAILABLE, IS THERE ANYTHING PEOPLE CAN DO TO MAKE SURE THEIR IMMUNE SYSTEM IS IN GOOD SHAPE?

Researchers have been studying the effects of diet, exercise, psychological stress and other factors on the immune response to COVID-19. There's good data to suggest that your general health does make a difference to how your immune system copes with COVID-19. Having high blood pressure or heart disease, or smoking, can increase the likelihood that you'll be hospitalised from COVID-19. Public Health England recently released a report on how being obese or excessively overweight increases the risk of illness and death from COVID-19 and there's some evidence of a link between vitamin D deficiency and COVID-19 severity.

"Maintaining a healthy lifestyle with regular exercise, a balanced diet, adequate sleep and minimal stress has been shown to keep our immune system strong and healthy," says Dr Madhvi Menon, a research fellow working at Manchester University's Institute of Immunology and Infection. "But very little is currently known about ways to avoid the severest form of COVID-19."

It's just as important to be sceptical about anything that claims to be able to 'boost the immune system' or ward off COVID-19. During the Spanish flu in 1918, which killed an estimated 50 million people, everything from onions to masturbation were touted as ways to boost the body's defences against the virus, and the pandemic of 2020 has been no different. Social media is awash with misinformation claiming anything from eating garlic to drinking silver can boost the immune system. Donald Trump, the US president, has added to the confusion by promoting the drug hydroxychloroquine as a preventative of COVID-19, when there is no good evidence that it is.

The best thing you can do to protect yourself is to not get COVID-19 in the first place. By adhering to guidance on social distancing, masks and frequent hand-washing, you're not only protecting yourself, but you're also helping prevent the disease spreading and saving vital health system resources for those who need it most. **SF**

by **TOM IRELAND** *(@Tom_J_Ireland)*
Tom is a freelance science journalist and editor of The Biologist, *the bi-monthly magazine of the Royal Society of Biology.*

BBC

Science Focus

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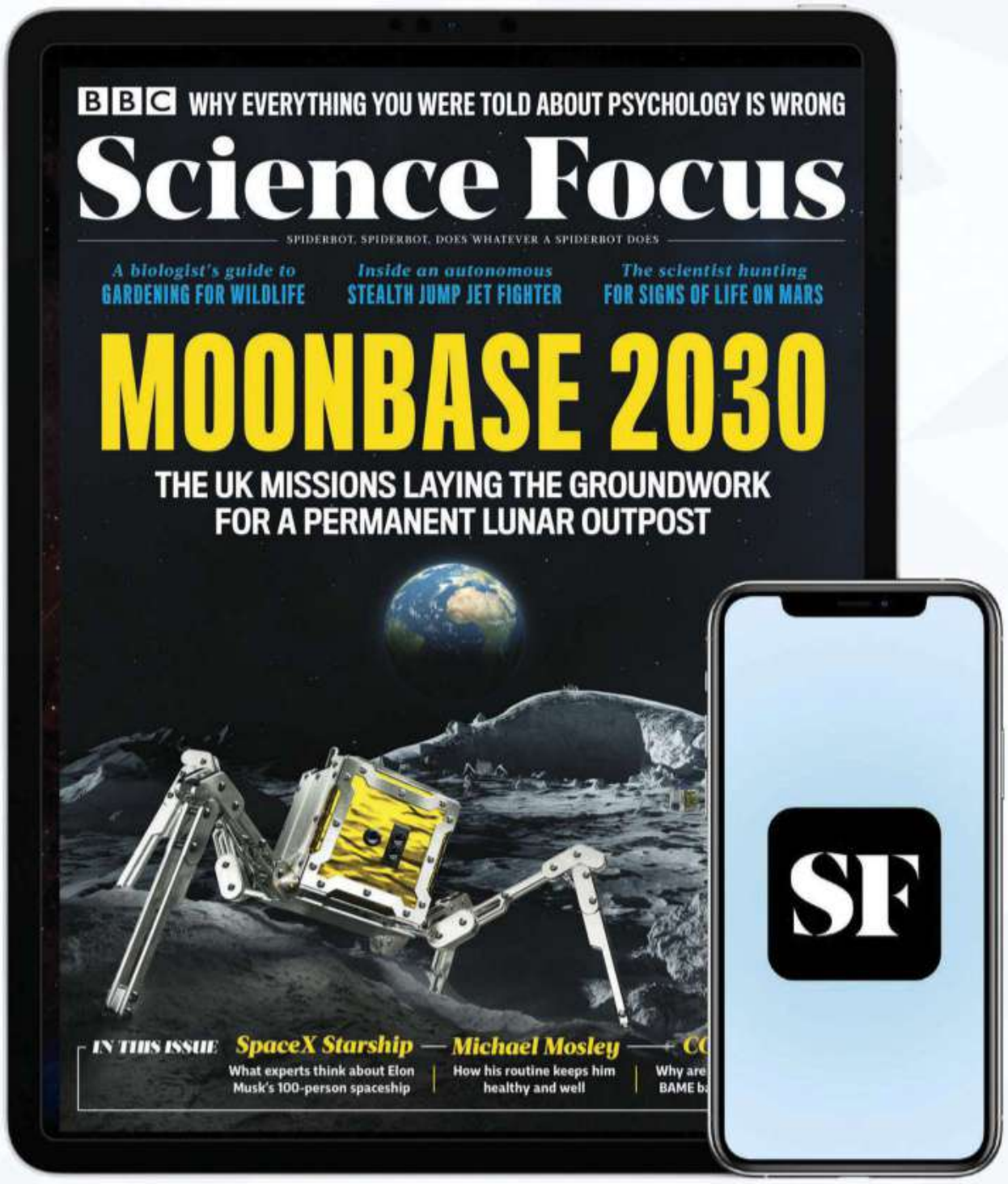
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COMMENT

IN PRAISE OF CAFFEINE

There's more to a cup of coffee than just an early morning pick-me-up

As I stagger out of bed in the mornings and begin my ritual of resistance exercises (press-ups, squats, sit-ups and the dreaded plank) the one thing that keeps me going is the promise of a lovely cup of tea when I get downstairs. After my first cup I take the dog for a walk, soak up the sunshine, then sip my first coffee of the morning, normally drunk black.

Apart from the flavour, what I love about tea and coffee is that they're stimulants, rich with the world's most widely consumed psychoactive drug, caffeine. A white, crystalline powder, it's produced by plants to protect them against insect attack.

Not only do tea and coffee perk me up in the mornings, but there is strong evidence that caffeine consumers enjoy a range of other health benefits, with the benefits being clearer for coffee than tea. A massive review of studies, 'Coffee consumption and health: umbrella review of meta-analyses of multiple health outcomes', published in the *British Medical Journal*, which looked at more than 220 studies, found that drinking coffee was associated with a significantly lower risk of heart disease and cancer, possibly because it's rich in antioxidants and other anti-inflammatory compounds. Coffee drinking was also associated with a lower rate of Alzheimer's and Parkinson's disease.

"As with most things, however, more caffeine is not necessarily better"

Based on this and other studies, the best 'dose' is between two and five cups a day. In terms of health benefits, the studies don't distinguish between instant coffee and brewed, but when it comes to caffeine content, a cup of instant coffee contains between 60-80mg of caffeine, while freshly brewed contains 60-120mg. A cup of tea, on the other hand, comes in at around 40mg of caffeine, depending on how long it's been brewed.

As with most things, however, more is not necessarily better. Drink more than five cups of coffee a day and the benefits tend to drop off. It's also unwise for pregnant women to drink lots, as it's linked to a slightly higher risk of prematurity and miscarriage.

Another downside to coffee, when it's drunk at night, is that it keeps some people awake. I'm sensitive to caffeine, but I also clear it from my system very fast, so I can drink coffee in the evening with no problems, while one cup in the afternoon has my wife twitching. The half-life of caffeine (the rate at which your body will clear half of what you've consumed) is anything from two to twelve hours and is largely dependent on your genetics and a liver enzyme called CYP1A2.

One of the things I should probably do is drink my coffee before my morning exercises, as studies show that coffee makes resistance exercise feel easier and reduces symptoms of fatigue. But I love the ritual of drinking coffee after a brisk walk too much to want to change the order, whatever the science suggests. SF

MICHAEL MOSLEY

Michael is a writer and broadcaster, who presents *Trust Me, I'm A Doctor*. His latest book is *Fast Asleep* (£9.99, Short Books).

BBC TWO

PORTRAIT: KATE COPELAND ILLUSTRATION: JOE WALDRON

COMMENT

BACK TO SCHOOL

After months of homeschooling, children are returning to the classroom. How can we ease the transition and help frazzled teachers?

Since March this year, I've been living for September. That's when the schools open again. It's when my kid can be taught by a professional who's not wrestling with worksheets while batting back conference calls and making excuses for missed deadlines. She'll be around people her own age, who challenge her in ways that have nothing to do with how much she eats, when she sleeps or how much *Vampirina* she's watched that day. September is when I can breathe again.

This is not a popular opinion on my social media. Once the US president made his proclamation about schools reopening, my feed became filled with angry epithets. "Think of the children." "Think of the teachers."

I promise you, I am.

I was a Class Parent – someone who facilitates communication between parents and teachers – in this pandemic year. When we moved to New York, I thought signing up for the job would be a fun way to get to know the other families in our new school. At the start, the role involved sending around notes from the monthly meeting, but from March to June it evolved into acting as a human shield between an angry mob of panicking parents and the teachers who, until this point, thought their job was to wrangle a roomful of six-year-olds. It turns out parents are an absolute nightmare.

ALEKS KROTOSKI

Aleks is a social psychologist, broadcaster and journalist. She presents *The Digital Human*.

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PORTRAIT: KATE COPELAND ILLUSTRATION: SCOTT BALMER

"Teachers guide our kids, they support them, they comfort them when things are bad"

And now that the date of re-entry approaches, boy do I feel for those teachers. After a summer of frustration and trauma, there are going to be some high expectations at the school gates. I have faith that the institution we send our child to will be working on solutions to tackle students' anxieties. Personally, I want to know what we can do to support the staff who have to deal with us.

"Teachers help us," says clinical psychologist Dr Tara Quinlivan, who wrote the influential blog post 'Return to school. A trauma-informed approach'. "They're really unacknowledged frontline and pastoral care workers." Teachers guide our kids, they support them, they comfort them when things are bad. They provide them with the skills to succeed in life. We cannot attack them. But we do. "They are the receivers of our distress and our concerns as parents. But we're not necessarily receiving their distress and their concerns in the same way," she says.

So what can we do? The emotional labour of holding our anxiety and stress – not to mention our kids' – is heavy work, and not what teachers signed up for. "I think the biggest thing we can do is remember that there is a human face behind all of this," Quinlivan says.

At the end of the school year, the Class Parents were offered a get-out-of-jail-free card. We were all ragged and broken, having endured the weight of our families' trauma in facing the uncertainty of a pandemic. Find a replacement, they said. And you are free. I don't know a single Class Parent who took it. We care about the teachers too much. All we want is for them to be free to be in the classroom again, without having to carry our emotional baggage. It's what they signed up for. And we can help give it to them. SF

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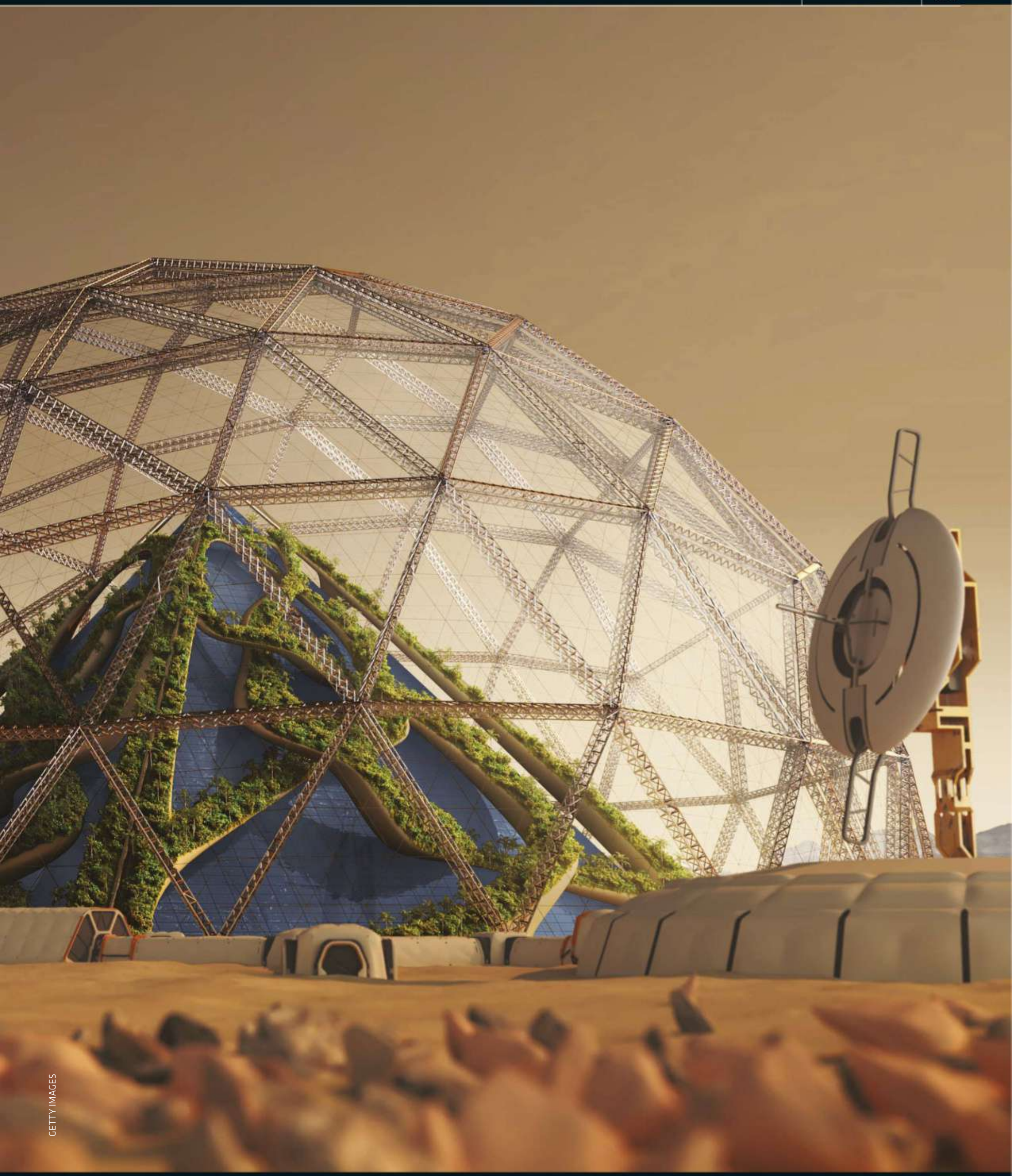
TURNING THE RED PLANET GREEN

If humans are to stand a chance of successfully setting up a colony on Mars, we're going to need to figure out a way of producing food on the Red Planet

WORDS **JAMES ROMERO**



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Four years ago, in 2016, Wieger Wamelink, a plant ecologist based at Wageningen University, sat down at the New World Hotel in the Netherlands with 50 guests for a one-of-a-kind meal. Things might have looked ordinary enough from a quick glance at the menu, if maybe a little cheffy – pea puree appetisers to start, followed by potato and nettle soup with rye bread and radish foam, then carrot sorbet to finish.

But the thing that made it such an extraordinary occasion was that all the vegetables used to make the meal had been grown in simulation Martian and lunar soils by Wamelink and his team.

Since then, they have grown an impressive 10 crops, including quinoa, cress, rocket and tomatoes using simulation soils produced using crushed volcanic rocks collected here on Earth. The team produced their simulant soil by grading the particles of rock into different sizes and mixing them in proportions that match rover analyses of the Martian soil.

The soils were initially developed so that rovers and spacesuits could be tested on Earth to see how well they handled the surface materials of Mars and the Moon. Few thought that the soils could ever actually be farmed.

For a start, there were concerns about the texture of the soil, especially after early attempts to farm model lunar soils struggled as a result of tiny, razor-sharp rock fragments that punctured the plants' roots. On Mars, though, the movements of ancient water and ongoing wind erosion have left a far more forgiving surface covering on the planet, and the simulation soils have proved to be successful.

Nutritionally, Wamelink says there's no difference between the 'Martian' crops and those grown in local soils, and when it comes to flavour he was most impressed by the tomatoes' sweetness.

Wamelink and his team are now attempting to improve crop yields by infusing the simulation Mars soil with nitrogen-rich human urine, a resource likely to be readily available on crewed missions to the Red Planet. He also plans to introduce bacteria that will fix more atmospheric nitrogen, and also feed on the toxic perchlorate salts present in Mars soil.

Elsewhere, at Villanova University in Pennsylvania, Prof Ed Guinan and Alicia Eglin are leading the Red Thumbs project, and have had several successes in farming their own Martian simulant. Initially derived from rocks gathered in the Mojave Desert, the Villanova researchers have augmented their model soil with earthworm farms, due to the animals' ability to release nitrogen from dead organic matter through their burrowing and feeding.

The Red Thumbs project made headlines in 2018 when the international media got excited about the prospect of Martian beer, after Guinan and Eglin's team managed to successfully produce barley and hops.

ABOVE Wieger Wamelink from Wageningen University checks on a batch of crops grown in simulant Martian soil

TOP RIGHT Potatoes don't fare so well in the tight, compacted Martian dirt

ABOVE RIGHT Potatoes grown in the simulation Mars soil were harvested, but the quality of the crop was varied

ALL THE SALAD YOU WANT, BUT NO CHIPS

A couple of years on and Guinan and Eglin have now added tomatoes, garlic, spinach, basil, kale, lettuce, rocket, onion and radishes to their greenhouses. The quality of harvests has varied, but chief among the successes was kale, which actually grew better in the simulant Martian soil than in local soils. Other crops struggled, such as the much-needed and calorie-dense potatoes. It turns out potatoes prefer more of a loose, uncompacted soil and failed to grow as the simulant soils became heavy and

"CHIEF AMONG THE SUCCESSES WAS KALE, WHICH ACTUALLY GREW BETTER IN THE 'MARTIAN' SOIL"

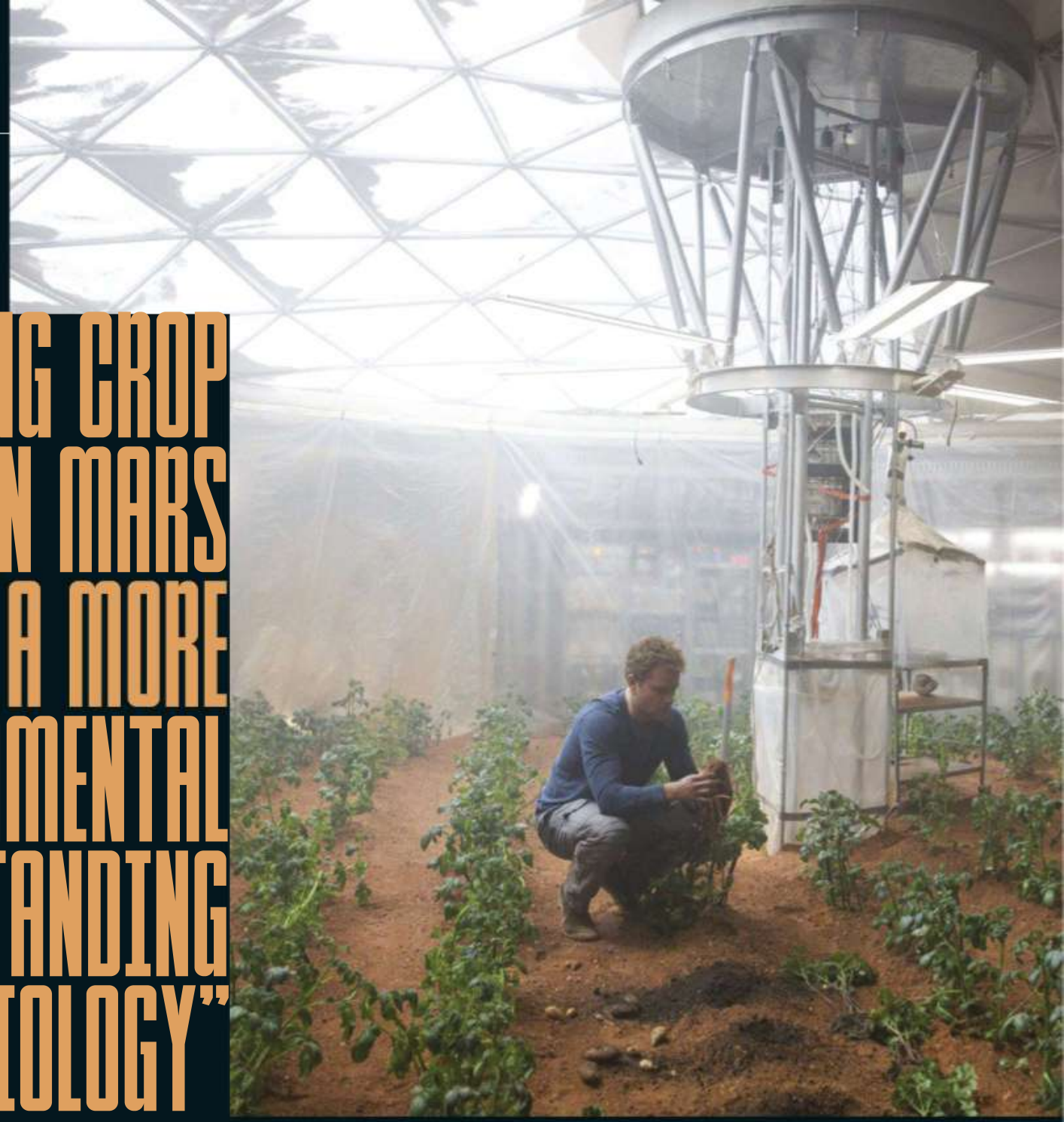
WIEGER WAMELINK X3

impenetrable when watered, which led to the potatoes being choked out.

Eglin believes that the key to success may be to grow lower yield crops that might enjoy more natural ecosystems than a single-species setup would allow. Even on Earth, agricultural monocultures often suffer over time as nutrients essential for that one plant being grown are progressively depleted and not replaced after each harvest.

To counteract this effect, farmers often introduce secondary species in the same growing area. These wouldn't compete with the main crop, because their root systems are shallower, but they would still offer additional nitrogen fixation to improve soil fertility. Eglin is now planning to test this by growing soybeans, which could prove to be a vital source of protein, and corn alongside pigweed, a leafy vegetable famous for its use in the Caribbean stew callaloo.

But however much success these projects have, we must remember that simulant soils have very real limitations, explains ESA's Christel Paille. She's involved in the Micro-Ecological Life Support System Alternative programme (MELiSSA), which is ▶



“PREDICTING CROP PERFORMANCE ON MARS WILL REQUIRE A MORE FUNDAMENTAL UNDERSTANDING OF PLANT BIOLOGY”

exploring a range of technologies for use in long-haul, crewed missions, such as bacterial bioreactors that recycle astronaut waste into air, water and food. While MELiSSA has provided support to Wamelink, Paille points out that any successes from the model soils must take into account the fact that they’re based on limited geographical sampling.

“It’s a baseline, but probably not something that we can generalise to any location on the Mars surface. We are always very cautious about a simulant material. It’s very difficult in a single simulant to capture all the characteristics [of the Martian surface],” she says.

Perhaps the only way around this is to collect a sample from the surface of Mars and return it to Earth. On 30 July, NASA’s Perseverance Rover launched from Cape Canaveral in Florida with its sights set on the ancient river delta deposits in Mars’s Jezero Crater. If all goes according to plan, next February the rover will find itself in what’s thought to be some of most fertile land on the Red Planet. Thanks to its plutonium-based power system, the rover should be able to spend up to a decade analysing the surface of Mars. While previous missions have looked for signs of habitable conditions that existed in the past, Perseverance aims to go one step further by searching for signs of past microbial life.

Also, and crucially for those with hopes of growing food on Mars, the rover will collect samples of rocks and soil, and store them in preparation for a potential future robotic mission to return them to Earth for analysis. Until then, the simulation soils are all we have to work with.

ESA, SHUTTERSTOCK

LEFT The MELiSSA programme is trying to create a self-sustaining life support system for plants that can be used for long-haul space missions

ABOVE Matt Damon successfully managed to cultivate crops while stranded on Mars in the 2015 film *The Martian*

There is still much to be learned in the meantime. For instance, rather than commit to individual species, Paille’s MELiSSA programme prefers to assess plants within a self-contained, life-supporting ecosystem. Here, the benefits of edible biomass, oxygen production and even water treatment are balanced against the resources to grow each plant and manage their waste. But predicting crop performance on Mars will require a more fundamental understanding of plant biology.

“It’s about going down to the molecular scale,” says Paille. “We need to characterise what’s happening underground, like in root respiration. How are gases such as oxygen taken up and provided to the root. And how does the carbon dioxide produced actually diffuse out?”

BARRIERS TO GROWTH

Even if a suitable simulant is developed, there are still other challenges to overcome. Mars is located in an orbit that’s around 70 million kilometres further out from the Sun than Earth. As a result, sunlight delivers only 43 per cent as much energy, leaving average temperatures languishing around

"THE MARTIAN ATMOSPHERE IS MUCH THINNER THAN EARTH'S AND LACKING IN THE NITROGEN VITAL FOR PLANT GROWTH"

-60°C. Also because of the planet's tilt and highly elliptical orbit, seasonal variations are extreme.

Another hurdle is the Martian atmosphere, which is much thinner than Earth's and lacking in the nitrogen vital for plant growth. Instead it's dominated by carbon dioxide, which is vital for photosynthesis, but it's at such low concentrations that any plants growing on the surface would struggle to harness enough to spur growth.

The thin atmosphere also exposes the Martian soil to cosmic radiation. This creates a hostile environment for any microorganisms you might introduce to recycle nutrients from dead plant matter. Also, Jennifer Wadsworth at the UK Centre for Astrobiology has shown that solar radiation can activate chlorine compounds in Martian soil, turning them into toxic perchlorate salts. These are poisonous if eaten and can lead to hypothyroidism, which blocks the release of metabolism-regulating hormones. Poisonous heavy metals such as cadmium, mercury and iron found in the soil also pose their own challenges.

FAR LEFT Prof Ed Guinan from Villanova University examines one of the plants being grown in the 'Mars Garden'

LEFT The Phase 2 Mars Garden, part of the Red Thumbs project

BELOW LEFT Guinan and two of his students tend to plants being grown as part of the Red Thumbs Project

JONATHAN GUST X3

"Everything that's poisonous for people you can think of in terms of heavy metals is in those soils," says Wamelink. "For plants it's not a problem because they'll store it somewhere. But if we eat those plants then it might be [a problem for us]."

Another option may be soil-less techniques already used on Earth. Aeroponics sees plants suspended in the air while their roots are sprayed with a nutrient mist. Alternatively, hydroponics dips the roots into a nutritious liquid. These approaches can produce larger, faster-growing crops, and have already been used to successfully grow lettuce on the International Space Station (ISS). In fact, the astronauts were so pleased with their harvest, says Wamelink, the scientists back home were disappointed with the amount of lettuce samples returned for analysis after too much was eaten.

CALORIE DEFICIT

Despite the popularity of the ISS lettuce, air or water agriculture alone may not be enough to sustain astronauts on long-haul trips to Mars, thanks again to the problem of growing potatoes.

"It's very difficult to grow potatoes in hydroculture, and just eating lettuce and tomatoes won't be enough because you need calories," says Wamelink. "Potatoes grow much better in soils, where you'll get a lot of harvest per cubic metre and the organic matter that you don't eat can be recycled."

Whether grown in soil, water or misty air, food will likely play much more than a simple nutritional role in any Martian outpost. Sitting down to a proper meal would prove invaluable for the mental health and comfort of any pioneering astronauts living millions of kilometres from home. Who knows, maybe rye bread and radish foam will be on the menu after all. SF

by JAMES ROMERO
James is a space and astronomy writer.

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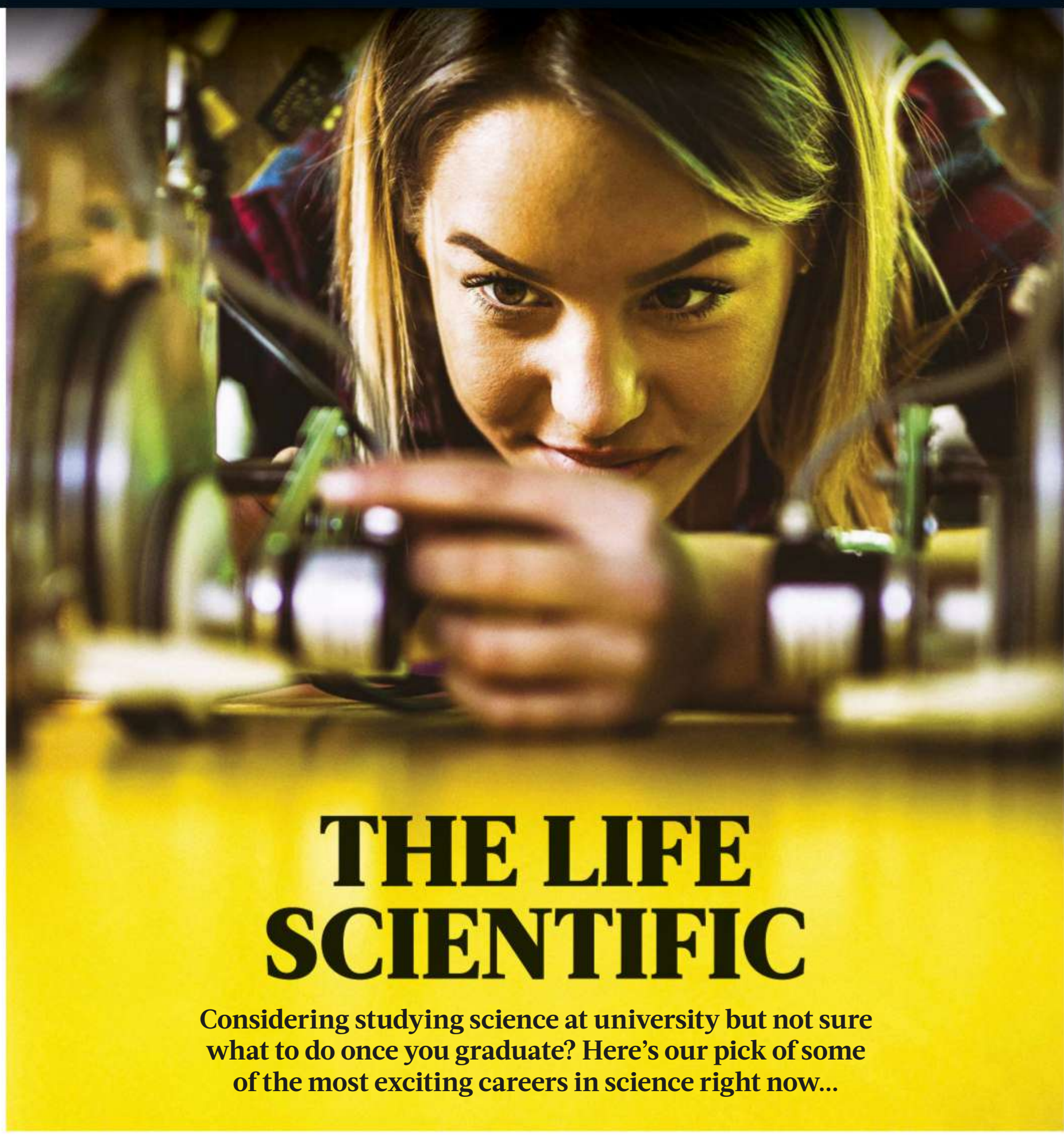

THE LIFE SCIENTIFIC

Considering studying science at university but not sure what to do once you graduate? Here's our pick of some of the most exciting careers in science right now...

GETTY IMAGES

LEANNE HEPBURN

Coral researcher

"There are organisms that build reefs up, such as coral and some algae, and there are organisms that break reefs down, such as coral-nibbling parrotfish and coral-eroding sponges. We study reefs in Indonesia, the Seychelles and the Persian Arabian Gulf, and look at the differences between reef production and erosion. We're worried, for example, that if sea level rises and erosion outstrips production that some reefs could effectively drown. We go on field trips every year and get teams of local divers to help us with our work. We measure everything from water quality and temperature to coral complexity and parrotfish numbers. Overall, I just love being underwater. We don't just collect data; we try to find ways to translate that data into science policy and management. Ocean optimism is really important. It's the only way we'll have an impact and ensure that we minimise future degradation of our coral reefs."

Dr Leanne Hepburn is a marine scientist at the University of Essex

GERD MASSELINK

Storm chaser

"Some people say we're like the tornado chasers in the film *Twister*. We watch the weather forecast for big offshore storms, then go and measure the impact the storm has on the coast. We drive quad bikes fitted with GPS over the beach so we can map its shape. We use drones fitted with GPS to map the dunes and launch probes from boats to map the part of the beach that is underwater. We do this all before and after the storm, so we can see how the storm changes things. It takes a crew of five or six people a couple of days to do. The data collection is fun, but then we need to analyse it, so we also do a lot of computer modelling. It's important work. Storm impacts will increase with climate change, so we need to understand the effect storms have on our coasts."

Gerd Masselink is professor of coastal geomorphology at Plymouth University

Paul Rowley

Venom milker

"How do you collect venom from a snake? Carefully! I'm the only person in Britain that routinely extracts venom from snakes. My job is the day-to-day feeding, cleaning, care and venom extraction of the 50 species in our collection, including mambas, cobras, rattlesnakes and saw-scaled vipers. To collect the venom, we secure the snake's body then gently grasp the head. The snake bites a petri dish that's placed in front of it, then we squeeze the venom glands and out it comes. These are snakes with bites that can cause long-term disability and death, so the venom is used to produce specific anti-venoms. One of the venoms I collected was used to make an anti-venom that saved 20,000 lives in sub-Saharan Africa. It's a really good feeling knowing you're having that kind of impact on people's lives."

Paul Rowley is senior herpetologist at the Liverpool School of Tropical Medicine

SANJA DOGRAMADZI

Roboticist

"I work as part of a multidisciplinary team to design and build intelligent robots that can solve clinical problems. When cancer patients have radiotherapy, for example, they have to keep very still so the treatment is delivered to exactly the right spot. Inevitably, they move, because the surface they have to lie on is so uncomfortable. We've made a comfortable, soft surface for patients to lie on, that detects movement and alerts the clinician so they can reposition the patient. We're also working on another system that stabilises the patient so that if they do move, it'll move them back automatically. One person alone couldn't solve this problem. It's really stimulating to work with people from different backgrounds – clinicians, radiographers, patients, engineers, physicists and technicians – and come up with devices that make a real-life difference. We create new concepts, solve problems and learn something new every day."

Prof Sanja Dogramadzi leads the Healthcare Robotics Group in Bristol Robotics Laboratory

GETTY IMAGES X4, ALAMY

ALEX BURTON-JOHNSON

Antarctic scientist

"It all builds up to the big field trip. Once every couple of years, I get to spend a couple of months at the bottom of the Earth. I fly to the Antarctic base in a Twin Otter plane that's like a Land Rover with wings. There, I meet my field guide; a highly trained mountaineer who's in charge of safety and logistics. We load up the snowmobiles and sledges with food and equipment, and then we head off to the survey site, which can be hundreds of kilometres away. We live together in the same tent for the next two months. My aim is to map the area geologically. Every day, we go out, climb mountains, chip away at the rocks and then collect and bring back samples. We're trying to find out how Antarctica was formed. The best bit is you get to explore these amazing landscapes that people have never been to before."

Dr Alex Burton-Johnson is a geologist for the British Antarctic Survey

EMMA LIU

Volcanologist

"I study the chemistry of the gases that are emitted from volcanoes because it helps us to understand the 'plumbing' beneath them and forecast when they might erupt. It's not always possible or sensible to collect samples directly from volcanoes, so I've been experimenting with long-range, high-altitude drones. Now we can fly them into a gas plume to collect measurements and samples, remotely and safely. My work takes me to amazing places. I was in Papua New Guinea four times last year. We discovered that the Manam volcano there releases huge amounts of carbon dioxide. It was a privilege to work with the local communities. They were as fascinated by us and our shiny gadgets, as we were by them and their beautiful culture. I also think we left a lasting impression because after we left, they set up their own Community Disaster Preparedness Committee to deal with future volcano hazards. It was wonderful to see and hear about that."

Dr Emma Liu is a volcanologist at University College London

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STEM online learning resources

Online learning has taken off in recent years with courses popping up on every subject imaginable. If you want a taster of what you might learn at university, here's our guide to what's available...

FUTURELEARN.COM

Learn new skills online with top educators
Learn with experts from world-leading universities and organisations
accenture

FutureLearn says 10 million people have studied the courses on its online platform since it launched almost eight years ago. When it began, in December 2012, it was partnered with 21 UK and two international universities; now FutureLearn is affiliated with over 175 institutions all around the world.

There are over 600 free short courses available on the site, 105 of which cover science, engineering and maths-related topics. You can try your hand at understanding the weather, data science in the games industry, and medicinal chemistry.

The courses are led by academics and aimed at school or college students looking for a taste of undergraduate study, but anyone can sign up to participate. Most of the courses are two to four weeks long and require less than five hours of study a week. There are videos, audio recordings, written articles and interactive quizzes to help you along the way. There are no grades or qualifications at the end of it but FutureLearn also offers 'microcredential' courses and some vocational degrees if you're prepared to pay.

KHANACADEMY.ORG

There are plenty of maths, physics, chemistry, biology, engineering and computing courses on the Khan Academy and they're all free (although you're encouraged to make a donation). The courses are geared towards kids of all ages in the US school system, whether they're just starting kindergarten (five years old)

or in the final stages of high school (16-18), but adults can sign up to study them too – as can almost anyone with an internet connection, since the courses have been translated into over 36 languages.

Each course is divided up into units with video lessons and reading materials to guide you through, as well as quizzes at various points and a test at the end. There are hints available to help you in the quizzes and tests, and further explanations of the specific problems are offered, whether you get the answers right or wrong. It's thorough and easy to use, but works best on devices with bigger screens.

BRILLIANT.ORG

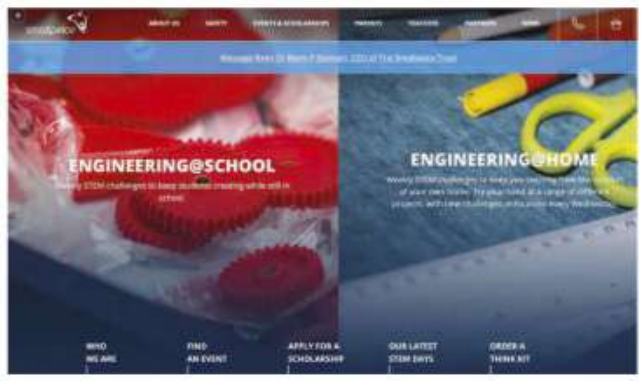
Visual learning, with a focus on science, maths and computing subjects, is at the heart of Brilliant.org. Its aim is to help students everywhere, of all ages, develop problem-solving skills and critical thinking abilities.

There are over 60 beginner, intermediate and advanced courses available, in everything from algebra, calculus and geometry, to chemical reactions, computational biology and Special Relativity, via artificial neural networks, machine learning, and programming with Python. Each course has been developed with help from teachers and researchers from the likes of MIT, Caltech, Duke University, Microsoft, Google and others.

Concepts are explained simply with animated demonstrations and your understanding of them is tested through interactive quizzes. Help, if it's needed, comes from fellow users whose explanations are voted up based on how useful they are.

There's a free trial option if you want to give it a go before committing, but getting full access to the courses requires a subscription, which costs £20.99 for a single month or £7.99 per month for a year.

SMALLPEICETRUST.ORG.UK



The Smallpeice Trust was founded in 1966 and set up to fuel a passion for engineering in kids at primary and secondary schools. Under normal circumstances, the Trust would do that by hosting workshops and events in schools or universities. But since that's not possible at the moment, the Trust has turned to promoting engineering online by posing weekly engineering challenges on its website.

Select the 'Engineering@Home' option (under the 'Parent' tab on the site's main menu) and you'll find a growing number of free challenges designed to help your child build, explore and test various contraptions, from rubber band-powered cars to prosthetic hands. The principles involved in each project are explained in a downloadable PDF and the construction materials are all things you're likely to have at home (egg cartons, straws, cocktail sticks, etc).

For older kids, there are also online courses in biomedical engineering (£50) and engineering experience (£50), with more to be announced over the coming weeks. Check the website for availability.

BRAINPOP.COM

BrainPop's aim is to help keep kids engaged by making learning fun. To that end, the website is brightly coloured, populated with cartoon characters and packed with educational resources in the form of short animated movies, activities and quizzes, as well as some related reading on each subject.

It's intended as an aid for teachers and parents of kids aged from five to early teens. BrainPop will run on a desktop, laptop, tablet or smartphone without you needing to download an app. Once you've signed in, the learning dashboard is easy enough for young kids to navigate and use unsupervised for the most part.

There's plenty of science material on there, with basic guides to everything from acceleration and asteroids to water pollution and wind energy, but you'll need a subscription to access most of it – family plans are available from $79-$159 (£60-£120 approx). Many of the games are free, though.

STAIRWAYLEARNING.COM

Stairway launched in 2019 and calls itself "a digital personal tutor for STEM subjects". It's aligned with the UK curriculum for secondary education, but can be used by anyone. The website is bright, friendly, free and fiendishly simple to use. You just tell it what you want to learn about (currently, your choices are physics, maths and biology), what exam board sets the assessments at your school, what you want your username and password to be, and then you pick a lesson and start learning.

Each lesson lasts about five minutes and is centred upon brief explanations of the concepts involved, often with some form of visual aid, and questions to get you thinking about and applying them.

Answering the questions correctly earns you points, while incorrect answers are rewarded with further clarifications of the idea being imparted. There are hints available if you're struggling, a summary at the end of each lesson and a blog with revision tips and advice on how to get the most out of studying at home.

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Q&A

YOUR QUESTIONS ANSWERED

... WHY AREN'T PTEROSAURS CLASSED AS DINOSAURS?
... IF NAPS ARE MEANT TO BE GOOD FOR ME, WHY DO I FEEL SO RUBBISH AFTERWARDS?
... WHY DO ONIONS MAKE ME CRY?
... WHO INVENTED SOAP?
... IS IT TRUE THAT WE ONLY USE 10 PER CENT OF OUR BRAIN?
... HOW CAN I SEE BETELGEUSE?
... WILL IT EVER BE POSSIBLE FOR A SAME-SEX COUPLE TO HAVE A BIOLOGICAL BABY TOGETHER?
... HOW DOES THE VOMIT COMET WORK?
... DOES A SPOON PLACED IN AN OPEN BOTTLE OF CHAMPAGNE KEEP IT FIZZY?

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ILLUSTRATION: DANIEL BRIGHT

ANITA HASHTRUDI, SCOTLAND

WHAT CAN THE WORLD DO TO AVOID FUTURE PANDEMICS LIKE COVID-19?

Unfortunately, the COVID-19 pandemic is unlikely to be the last one that we experience. But there are things that we can do on a societal and national level to minimise the chances of a new pandemic occurring, and to ensure that the world is better prepared when one does occur.

Pandemic-causing viruses typically circulate in a population of animals before they jump to humans. So cutting down on activities that put us in close contact with wild animals, such as wildlife trading and 'wet' markets, will reduce the chances of a virus jumping from animals to humans. Tackling deforestation and climate change will also help, as both of these problems can lead humans to migrate into new areas where wild animals live.

Second, we need countries around the world to strengthen their surveillance of existing viruses, and we need to watch for any new viruses emerging in wild animals. The coronavirus that causes COVID-19 is thought to have originally come from bats, but viruses can reside in many other animals, including pigs, monkeys and birds. We also need systems in place so that any new type of human infection is rapidly identified and globally reported.

Finally, we need to strengthen countries' public health infrastructure. At the start of the COVID-19 pandemic, many countries struggled to develop robust national testing and tracing programmes. With these programmes in place, we would be able to contain new outbreaks more rapidly. We can also ensure that we have vaccine development and manufacturing facilities in place that can rapidly create vaccines for new diseases. ***JR***

NEIL BLACK, SHEFFIELD

WHY AREN'T PTEROSAURS CLASSED AS DINOSAURS?

Pterosaurs (flying prehistoric reptiles) and dinosaurs (also reptiles) share a common reptilian ancestor that lived some 240 million years ago, but the two groups then followed different evolutionary paths. Dinosaurs are characterised by distinctive features of the skeleton, including a window-like opening in the pelvis where the thigh bone connects. Pterosaurs don't have this joint, and they have their own unique features such as extra-long fourth fingers that support their wings. Pterosaurs are no more dinosaurs than we are chimpanzees. ***SB***

CHRISTIAN (AGED 10), HERTFORDSHIRE

WHY DO ONIONS MAKE ME CRY?

The onion's cells contain an enzyme called alliinase and chemical compounds called sulfoxides. Normally the alliinase and sulfoxides are kept apart, but when the onion is chopped, they are released and react to form sulfenic acid. This acid is then acted on by a second type of enzyme called a synthase, which produces a gas called 'syn-propanethial-S-oxide'. This diffuses through the air and irritates your eyes, prompting your tear glands to produce tears to flush it out. ***LV***

CROWDSCIENCE

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WHO INVENTED SOAP?

The making of soap dates back at least 5,000 years to the Sumer region (now southern Iraq) in Bronze Age Mesopotamia. Sumerian texts from that era give brief descriptions of ways of making soap from the resin of conifers such as fir trees. These techniques were later expanded by the Babylonians and Egyptians, who devised new forms of soap made from plant ash, oils and animal fat. The end result had the same basic properties as modern soaps: when combined with water and agitated they created a lather and helped remove dirt.

Soap originally seems to have been used primarily for the treatment of ailments. One Sumerian text dating back to 2200 BC describes a form of soap being used to wash a person who seems to have had some type of skin condition. Exactly what the physicians believed this would do is unclear, but the idea that soap had medical benefits was accepted by many ancient civilisations.

It's now known that they were on to something. In creating soap, they had stumbled upon a way of producing a substance made from dirt-removing, tadpole-like molecules. When mixed with water, these molecules form spherical structures called 'micelles' around any droplets of germy dirt or oil, with their water-hating ('hydrophobic') tails pointed inwards and their water-loving ('hydrophilic') heads pointed outwards. The outside of the micelle is soluble and so it washes away, along with any grime trapped in the middle. ***RM***

NICK TUPPER, LONDON

WILL IT EVER BE POSSIBLE FOR A SAME-SEX COUPLE TO HAVE A BIOLOGICAL BABY TOGETHER?

Only time will tell. The idea is that one day, scientists might be able to take regular cells – maybe skin or blood cells – from two same-sex parents, use gene-editing to turn them into stem cells (which can develop into any cell type in the body), and then coax these stem cells into becoming sex cells. Cells from one partner – male or female – could be used to make eggs, while cells from the other male or female partner could be used to make sperm. Then in vitro fertilisation (IVF) could be used to make a baby.

In October 2018, Chinese scientists revealed that they'd performed a similar procedure in mice, and created mouse pups from same-sex parents. The same month, scientists from Japan announced that they'd made human eggs from blood cells. The prospect of human babies from same-sex parents had moved a step closer, but the studies also highlighted just how difficult the procedure is likely to be. The human eggs were difficult to grow and didn't mature properly, and although healthy mouse pups could be made from two mothers, pups with two fathers died shortly after birth.

In addition, the stem cells used to make the mice had to be genetically modified in order to give the mouse embryos the best chance of survival (the same would have to be done with human same-sex babies). Despite this, out of 210 embryos created, only 29 survived. For the foreseeable future at least, the stakes are too high, and the process too unpredictable, to consider using on humans. ***HP***

DEAR DOCTOR...

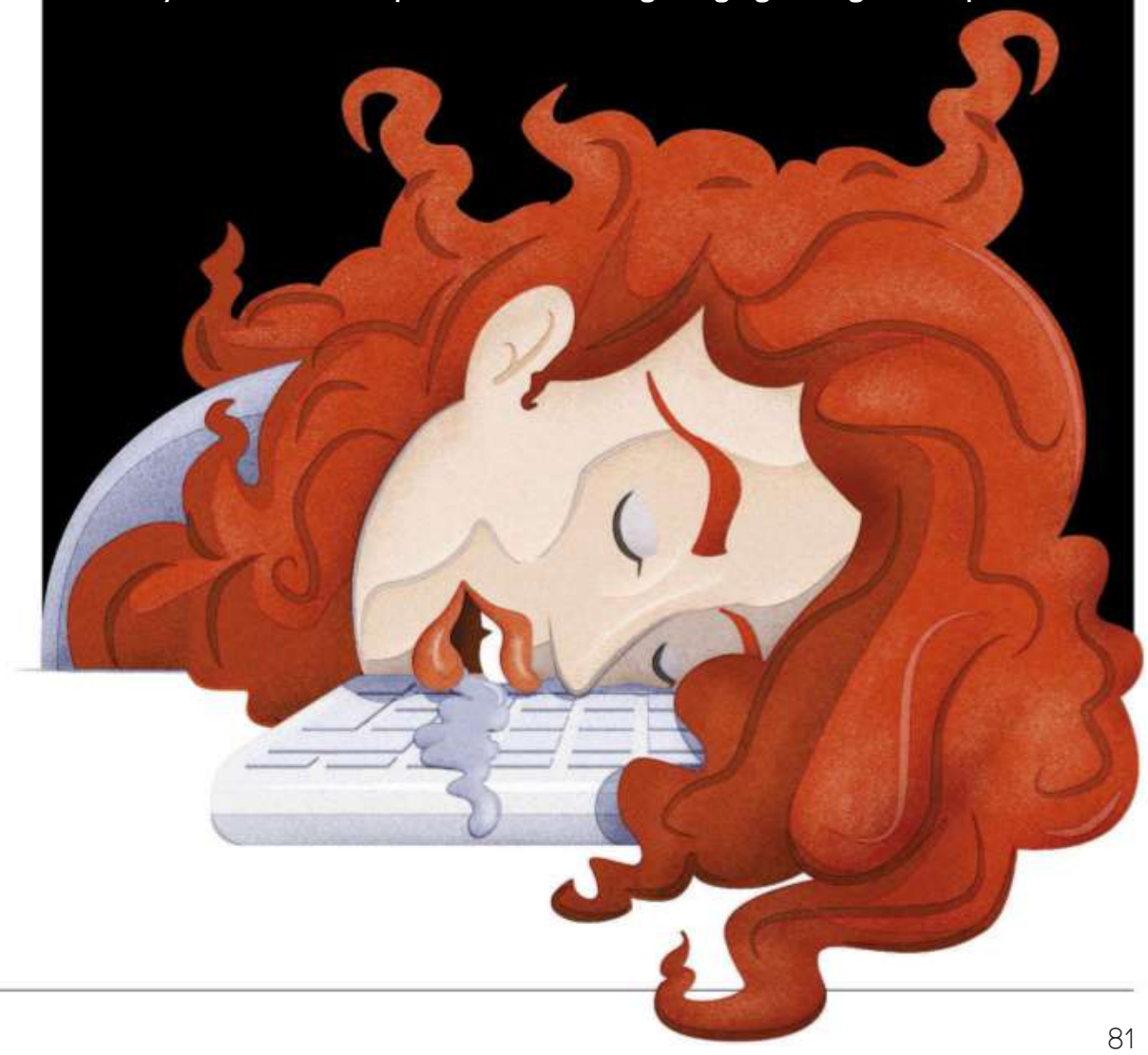
DELICATE ISSUES DEALT WITH BY *SCIENCE FOCUS* EXPERTS

IF NAPS ARE MEANT TO BE GOOD FOR ME, WHY DO I ALWAYS FEEL SO RUBBISH AFTERWARDS?

Sleep scientists have found lots of benefits for naps. Napping can help to reduce stress, boost the immune system and improve our mood. Post-lunch naps can help us to stay alert and improve our performance at work, and there's even evidence, albeit from small studies, supporting the 'nappuccino', where people drink coffee just before a nap – and reportedly wake up feeling recharged from the combination of caffeine and sleep.

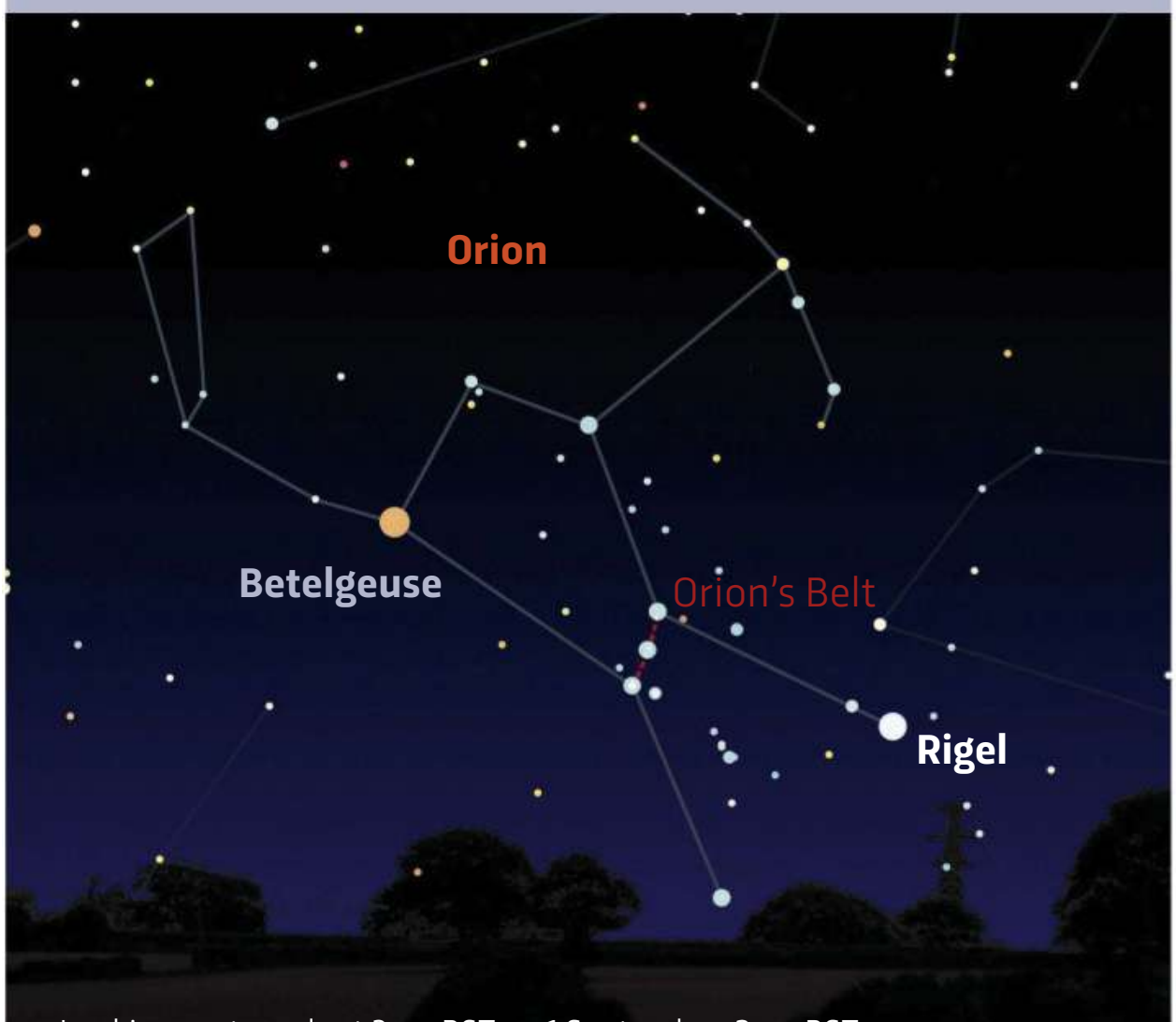
Despite all this, naps are not for everyone. Many people wake up feeling groggy. This state is known as 'sleep inertia', and it's more likely to happen when we nap for longer than 20 minutes. It's not known exactly what causes sleep inertia, but it may involve a molecule called adenosine, which builds up in our brain during waking hours, and decreases during sleep. Grogginess may result if the adenosine hasn't fully cleared by the time we wake up. But even short naps have the potential to cause this state (one reason why we should always give ourselves time to fully wake up before, for example, driving). Napping can make us less sleepy at night, so it's not recommended if you have insomnia.

Genetics appears to play a role in how long infants nap for, so our genes might help to explain why some people feel good after a nap, while others don't. If napping isn't for you, don't feel pressured, but instead work on getting a good night's sleep! *AGr*



GETTY IMAGES X2, ALAMY X2 ILLUSTRATIONS: DANIEL BRIGHT

ASTRONOMY FOR BEGINNERS



Looking eastwards at 3am BST on 1 September, 2am BST on 15 September and 1am BST on 1 October

HOW CAN I SEE BETELGEUSE?

SEPTEMBER UNTIL APRIL (EVERY YEAR)

Betelgeuse is one of the most iconic, and brightest, stars in the night sky. If you want to start learning the names and positions of specific stars, it's a great place to start. The star's name has its origins in Arabic, and there's no consensus on whether the 'g' is hard or not in the Westernised version. But a common way of pronouncing it is like the 1988 film *Beetlejuice*.

You can see Betelgeuse with the naked eye. To find it, look first for the three stars that make up Orion's Belt. This famous star pattern ('asterism') will be rising above the eastern horizon at 3am at the start of September, getting earlier each night (by the end of September, it'll rise just after 1am). Next, look for the bright, reddish star up and to the left of the belt. This is Betelgeuse, which marks Orion's right shoulder (or left as we look at it). If you miss the star in September, don't worry – it'll be visible until next April.

Betelgeuse's colour is due to the fact that it is an ageing 'red supergiant' star, over one billion kilometres in diameter (that's nearly 1,000 times the size of our Sun). Like other red supergiants, it will end its life by exploding in a dramatic supernova. This will be so bright that we can see it during the daytime on Earth.

In October 2019, Betelgeuse started to become unusually dim, prompting speculation that it was about to explode. But the dimming stopped in February 2020, and it turned out to be due to huge cool patches, or 'starspots', on the star's surface. The current best estimate is that the supernova will happen within the next 100,000 years, so it's likely we have plenty of time to enjoy the red shine of Betelgeuse in the night sky. ***AB***

ADAM KING, HUDDERSFIELD

COULD WE ERADICATE THE COMMON COLD IF EVERYONE SELF-ISOLATED?

The common cold is a global disease which can be caused by more than 200 different strains of virus. Most people are infectious for a day or two before symptoms appear, and remain infectious for one or two weeks. So to stamp out the cold, we'd need to self-isolate for at least a week after showing any symptoms, and there would need to be a 'test and trace' system to identify anyone who we may have been in contact with before symptoms appeared. The economic, mental health and physical health costs of so many people self-isolating would vastly outweigh the benefit of eradicating the cold. ***LV***

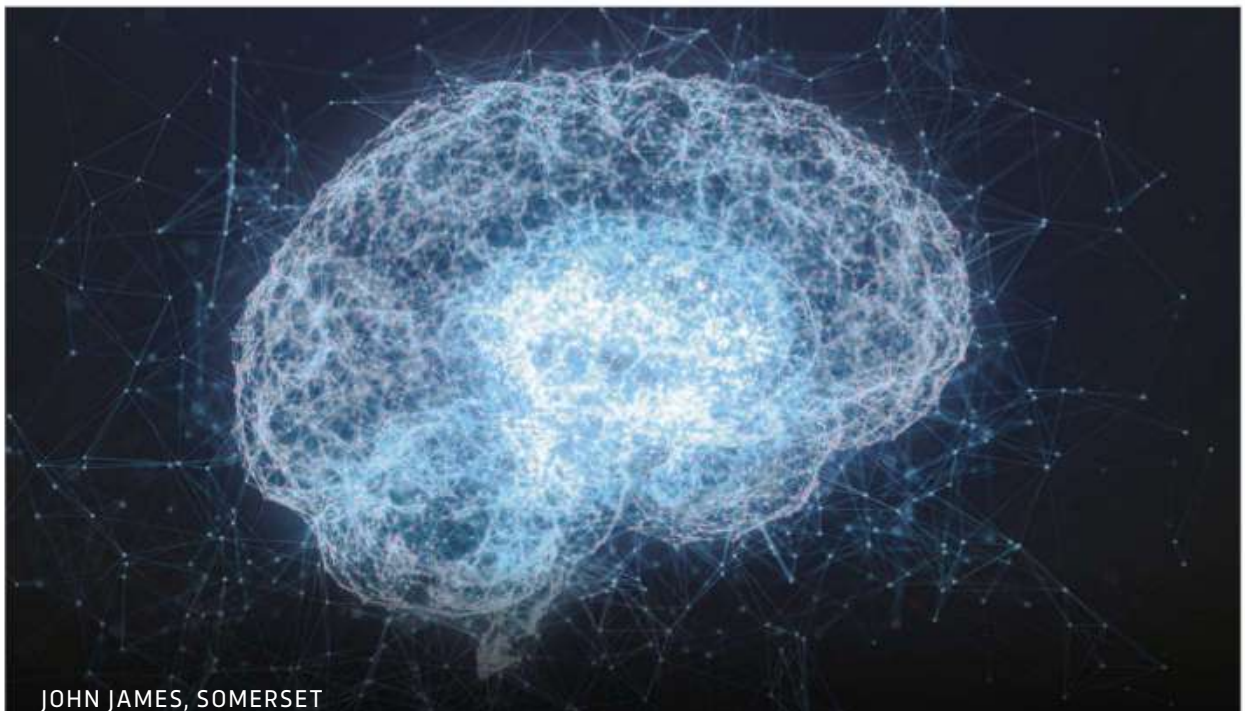
6,739

The altitude, in metres, that a yellow-rumped leaf-eared mouse was found at, making it the world's highest-dwelling mammal – a new record.

TIM MCGREGOR, BRISTOL

I LOVE WEARING MY PYJAMAS WHEN I WORK FROM HOME, BUT COULD IT BE AFFECTING MY PRODUCTIVITY?

Common sense and lived experience tell us that what we wear affects our mindset. Whether it's a chef donning his apron or a dentist putting on her white coat, work attire helps us to get into role. Supporting this idea is a psychological effect known as 'enclothed cognition'. In a seminal study published nearly a decade ago, researchers at Northwestern University in Illinois, US, showed that volunteers performed better on attention-related tasks when they put on a doctor's lab coat. Other findings hint at the same principle – in 2014, for instance, US researchers found that volunteers negotiated more effectively (and had higher testosterone levels) when they wore a black suit, compared with others who wore a tracksuit. So even though your colleagues might not be able to see you in your pyjamas, you could indeed be losing out on the psychological benefit of dressing for work. After all, pyjamas tend to be associated with sleep and inertia! As well as considering what you wear, other tips for increasing productivity when working from home include setting aside specific hours for work (and letting close friends and family know that you'll be unavailable) and, if you can, carving out a specific space for doing your work: somewhere you can't reach the TV remote or see the dishes piling up. ***CJ***



JOHN JAMES, SOMERSET

IS IT TRUE THAT WE ONLY USE 10 PER CENT OF OUR BRAIN?

This is an urban myth: scans show that most of the brain is active even when we're not doing much. It's true that brains are adaptable, and we have huge potential to learn new skills, but this happens mostly via the formation of new connections and networks in the brain, not through the activation of previously idle areas. The brain is a huge energy-guzzler, and it wouldn't make sense for us to have evolved to use a fraction of such a costly organ. *CJ*

GETTY IMAGES X6, PETE LAWRENCE ILLUSTRATION: DANIEL BRIGHT

WHAT CONNECTS...

MADAGASCAR AND BEAVER BUMS?

1.
Madagascar (pictured) is the world's principal producer of vanilla: in 2018, it produced 41 per cent of vanilla worldwide. The vanilla spice is harvested from the seed pods of the *Vanilla planifolia* orchid.

2.
Vanilla is the UK's most popular ice cream flavour, according to a 2020 survey of ice cream parlours. Mint choc chip was in second place, with chocolate in third.

3.
Vanilla ice cream is flavoured with vanillin. This is the main substance in natural vanilla extract, but today vanillin is usually made artificially using a raw material from the petrochemical industry called guaiacol.

4.
If that sounds bad, vanilla flavourings have also been known to contain castoreum – a yellowish, butter-like secretion from pouch-like sacs on beavers' bottoms. Described as having a 'warm, animal-sweet' scent, castoreum is happily rarely used in foods today.

OLD WIVES' TALES...

PUT A SPOON IN AN OPENED BOTTLE OF CHAMPAGNE TO KEEP IT FIZZY

It's the end of the night, and a half-drunk bottle of champagne lies open before you. How do you keep it fizzy for the next day?

Many people swear by a simple trick: stick a spoon – preferably silver – into the neck of the bottle, handle down. Do this and chances are there'll still be some fizz in the morning. The thing is, of course, this doesn't prove the spoon had anything to do with it; the fizz may have remained without it.

In 1994, the spoon trick was put to the test by Prof Richard Zare, a chemistry professor at Stanford University, California. He asked a panel of eight amateur tasters to judge the fizziness of champagne poured from 10 bottles. Some had just been opened, while others had been left for 26 hours with either nothing, or a spoon made of either silver or stainless steel in their necks. The judges weren't told how each bottle had been treated. The conclusion: none of the spoons had any real impact on the fizziness – a finding later confirmed by the professional association of champagne producers in France.

So what's the best thing to do? Get yourself a stopper, and keep the drink in the fridge. Carbon dioxide gas, which gives champagne its fizz, is more soluble in colder liquid, so the bubbly will better retain its sparkle. *RM*

MEGHANA VIPIN

CAN WILD ANIMALS BECOME OVERWEIGHT?

In 2019, firefighters in the German town of Bensheim rescued a chubby rat that had become stuck trying to squeeze itself through a small gap in a manhole cover. The rotund rodent was sent on its way with a valuable life lesson: that overeating isn't necessarily a good idea. Overweight animals are slow and vulnerable to predation, so don't last long. The animals we think of as fat – seals, walruses and polar bears – aren't overweight at all. Their blubber is an adaptation that offers buoyancy, insulation and energy storage, so sometimes it's all about survival of the fattest. ***HP***

MEGAN BAKER

HOW SMALL WOULD THE EARTH HAVE TO BE FOR US TO FEEL IT SPINNING?

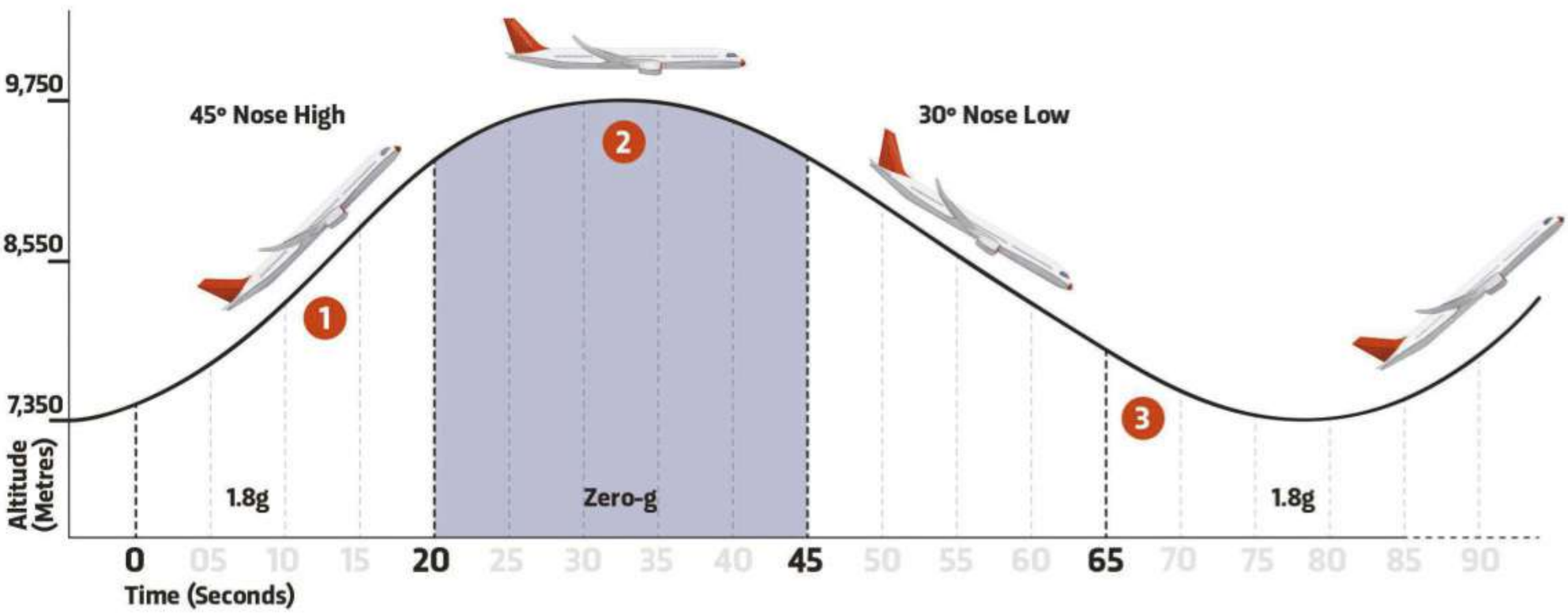
We can't feel the rotation of the Earth directly, because we are rotating with it. But if the Earth somehow compressed itself without losing any mass, it would have to spin faster to conserve its angular momentum – like the pirouetting ice skater so beloved of physics teachers. This would increase the centrifugal force acting on us, and because this force acts radially outwards, it would partly cancel out the force of gravity, and our weight would decrease. Halving the diameter of the Earth would reduce our weight by around 1.2kg, which is probably not enough to notice. But centrifugal force doesn't increase linearly, and on a quarter-sized Earth your weight would drop by 15kg in total, so you would feel lighter and could jump higher.

Whether this counts as feeling the rotation itself is debatable. On a merry-go-round, you feel the spinning because the radius of the ride is so small that the centrifugal force varies noticeably across the length of your body. For this to happen, our miniature Earth would have to be so small that your own height was a significant proportion of the planet's radius. Long before we reached that point, though, the Earth would have disintegrated from its own centrifugal force. *LV*

HAYLEY PATERSON, BOURNEMOUTH

HOW DOES THE 'VOMIT COMET' WORK?

On a standard aeroplane flight, you experience two forces in the vertical direction: the Earth's gravity, which pulls you (and the plane) downwards, and the plane's lift, which pushes upwards against you. If the aeroplane was to go into freefall, both you and the plane would experience the same gravitational acceleration downwards, but the plane would no longer provide the upwards force to cancel it out. This would give you the experience of weightlessness, and you'd float around inside the cabin. ***LV***



1. Ascent
The plane climbs 2,400 metres, from 7,350 to 9,750 metres, at a 45° angle to gain height for the manoeuvre.

2. Freefall
As the plane nears the top of its trajectory, the engines are cut back. The plane coasts to its highest point and begins to fall, while the passengers inside experience weightlessness.

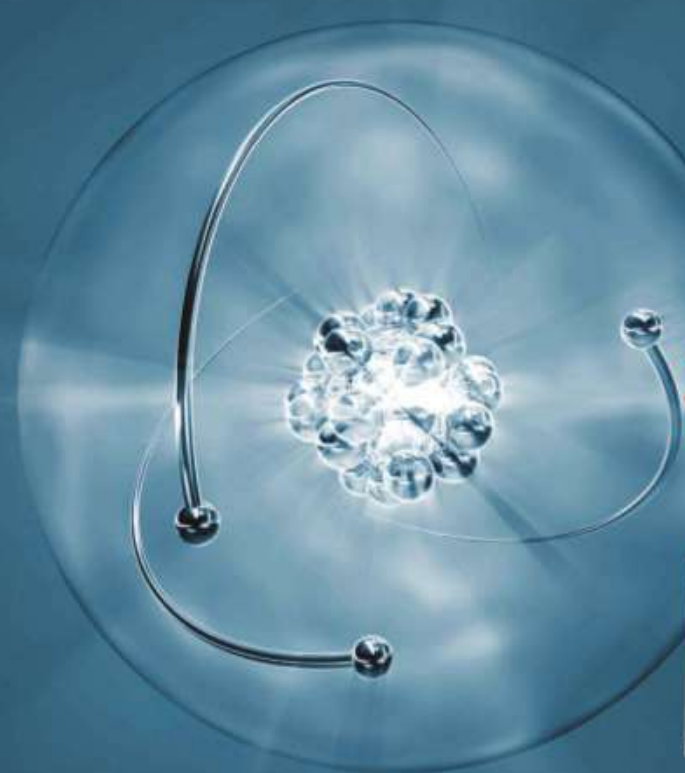
3. Pull up
The plane pulls out of its 30° dive and the passengers experience of g-force of 1.8 as they climb again. This sequence is repeated as many as 60 times in a single flight.

QUESTION OF THE MONTH

HARVEY SMITH

IN AN ATOM, WHAT FILLS THE SPACE BETWEEN PARTICLES?

At school, we're taught to picture atoms as a kind of mini solar system, with electrons as tiny 'planets' whizzing around the nucleus. So it's natural to think that most of the atom is nothing but empty space. However, quantum theory has revealed a far stranger reality. Rather than solid objects orbiting the nucleus, the electrons are more like fuzzy clouds whose density varies from place to place. This cloud-like nature of electrons means that there's a probability of them being anywhere in the atom, making it meaningless to talk of empty space lying between them and the nucleus. *RM*



WINNER

Harvey wins a bundle of six classic science fiction books from Penguin Classics, worth £53.94. The prize includes *The Hair-Carpet Weavers*, *We*, *Trafalgar*, *10,000 Light-Years From Home*, *Dimension Of Miracles* and *Flatland*. **penguin.co.uk**

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GETTY IMAGES X2 BERUFSTIERRETTUNG RHEIN NECKAR, ALAMY ILLUSTRATION: DANIEL BRIGHT

THE EXPLAINER

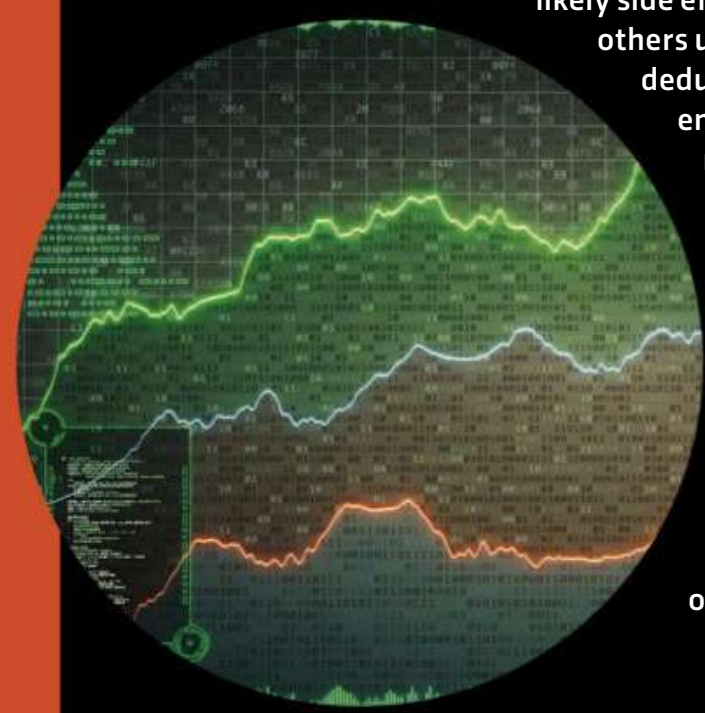
WHAT IS ARTIFICIAL INTELLIGENCE?

WHY IS ARTIFICIAL INTELLIGENCE SO POPULAR TODAY?

Artificial intelligence (AI) has been around since the birth of computers in the 1950s. The original pioneers dreamed of making 'computer brains' that could perform the same kinds of tasks as our own brains, such as playing chess or translating languages. But hopes that AI would quickly reach human-level intelligence didn't come to fruition, and AI soon fell out of favour. Over the following decades, technology improved at an exponential rate. Computers got faster, the internet was invented, and researchers made new advances in AI algorithms. In the last decade, AI has started solving many of the problems that we always dreamed it could. This has prompted billions of dollars of investment from companies, governments and financiers, and many major organisations now embrace AI as a core element of their business.

ARE THERE DIFFERENT KINDS OF AI?

Mention AI, and most people think of 'deep learning'. This kind of AI is loosely inspired by the way our brains work. It uses lots of computers to simulate large networks of artificial 'neurons', which are then trained, typically using humongous amounts of data, until they've learned to do what we want them to – for example, understanding speech. This training is the slow and resource-heavy part. Once trained, even a phone can then run the AI and instantly perform the right function, such as obeying your voice command. Deep learning is just one kind of AI, among thousands of others. Some AIs use advanced statistics to help computers make predictions, such as the likely side effects of a new drug; others use logic to make deductions about their environment, such as a robot mapping out a route; while others simulate evolution or even swarms of bees in order to find solutions to difficult problems such as scheduling activities in a factory or optimising the shape of an aircraft wing.



GETTY IMAGES X6

Artificial intelligence still cannot drive a car as well as an experienced driver

CAN WE TRUST AI?

There are always downsides to technologies. If an AI is trusted too much, then we may get ourselves into trouble – this is why self-driving cars will always need a human override option. If we train AI with biased data then the AI will also be biased, as studies have shown where AIs recognise white male faces better than others. Some worry that AI will lead to job losses, which may be true, but AI will also create many jobs. AI is nothing new in this regard: a similar thing happened in the Industrial Revolution, and again in the 'information revolution' with the advent of computers and the internet. In the end, AI should not be feared. AI is being created to help us, and like all technologies, we need to ensure that it is used appropriately.

WILL AI EVER BE AS CLEVER AS US?

This is a tough question, as it depends how we measure intelligence. The more advanced AIs can recognise features in images (that's a half-hidden cat; that's a corner of a bus) better than us, provide expert opinions more reliably than us (your test results mean you have an 85 per cent chance of condition X), and play many games better than us – most recently Go and classic arcade games like *Asteroids*. But no AI can drive a car as well as an experienced driver, despite billions of dollars of research and data equivalent to more than 10 billion miles of driving. No AI can control a robot to wash the dishes. No AI has an IQ more than that of an average six-year-old child. We have very powerful computers, lots of training data, and some clever algorithms, but we still don't know how to make an AI with the flexibility and learning capacity of the human brain – and we also don't know how to make AIs that become cleverer without human input. What's more, we still don't fully understand how intelligence arises in biological organisms, so it's hard to see how our human-inspired AIs will match our intelligence in the near future.

A robotic arm plays Go against a human opponent at an AI conference in Shanghai

WHAT ELSE IS AI USED FOR?

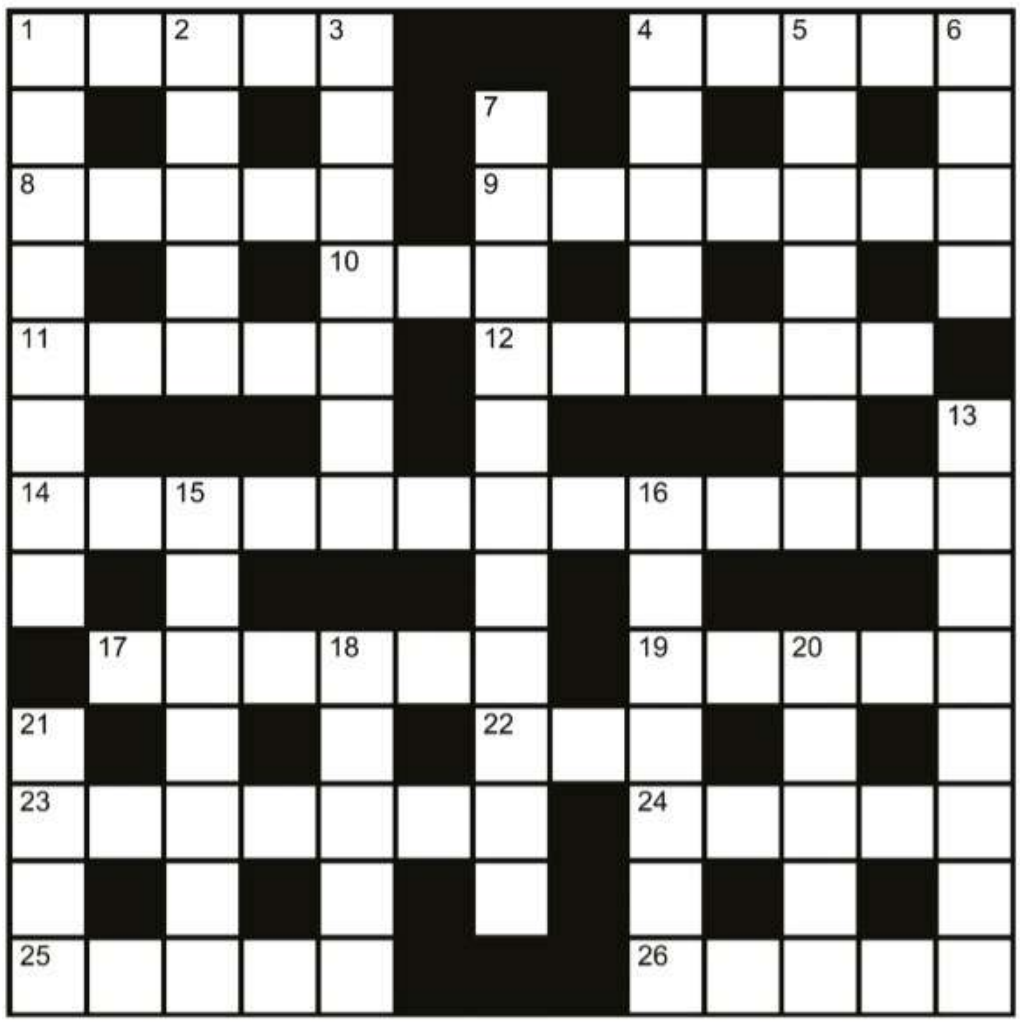
AI has become a ubiquitous technology. When you unlock your phone by looking at it, an AI has recognised your face. When you speak to your TV or smart speaker, an AI has recognised your voice. When you take a photo with your phone or digital camera, an AI identifies elements in the foreground to help blur the background, and combines several photos taken with different exposures to construct a perfect picture. AIs check for fraud every time you buy something online. They monitor your online shopping behaviour and present you with adverts tailored to your likes. They suggest news stories that you are more likely to be interested in, and answer your questions in online help desks. AIs are creative, composing music, designing buildings, painting artworks. AIs are also enabling our vehicles to become increasingly autonomous, taking over some of the more tedious and repetitive aspects of driving.

by PROF PETER J BENTLEY

Peter is a computer scientist at University College London and author of 10 Short Lessons In Artificial Intelligence And Robotics *(£9.99, Michael O'Mara Books).*

CROSSWORD

GIVE YOUR BRAIN A WORKOUT



ACROSS

1 Some information attorney must return without having succeeded (5)
4 Six leave, having registered sign (5)
8 Ingredient of bloomer, say (5)
9 Cheerful, left sand around hilly terrain (7)
10 Encourage farm produce (3)
11 Drive back to see film about parking (5)
12 Articles right behind part of flower (6)
14 Vehicle, once abrupt, arranged for waste management (6,7)
17 One brie, a variety from a peninsula (6)
19 Audible is audibly permitted (5)
22 Not going back a great deal (3)
23 Imagine endless choice - true confusion (7)
24 Cruel sort of complaint (5)
25 Scandinavian has time for an Italian writer (5)
26 Small desire for sudden movement (5)

DOWN

1 Disagree, lacking energy, perform and spread out (8)
2 Tenor upsets poor soldier (5)
3 Cherry is extra large to behold (7)
4 Manservant medic has a trainee (5)
5 Poem on a rude composition (7)
6 Roasting outside kiln (4)
7 Cad's outrage somehow made more attractive (5-6)
13 Information involving armed policeman (8)
15 Gem, almost a symbol, a red line (7)
16 Strip for very little money (7)
18 Journey about to get unacceptable (5)
20 Mark round to start award (5)
21 Unexpected ingredient in his pudding (4)

ANSWERS

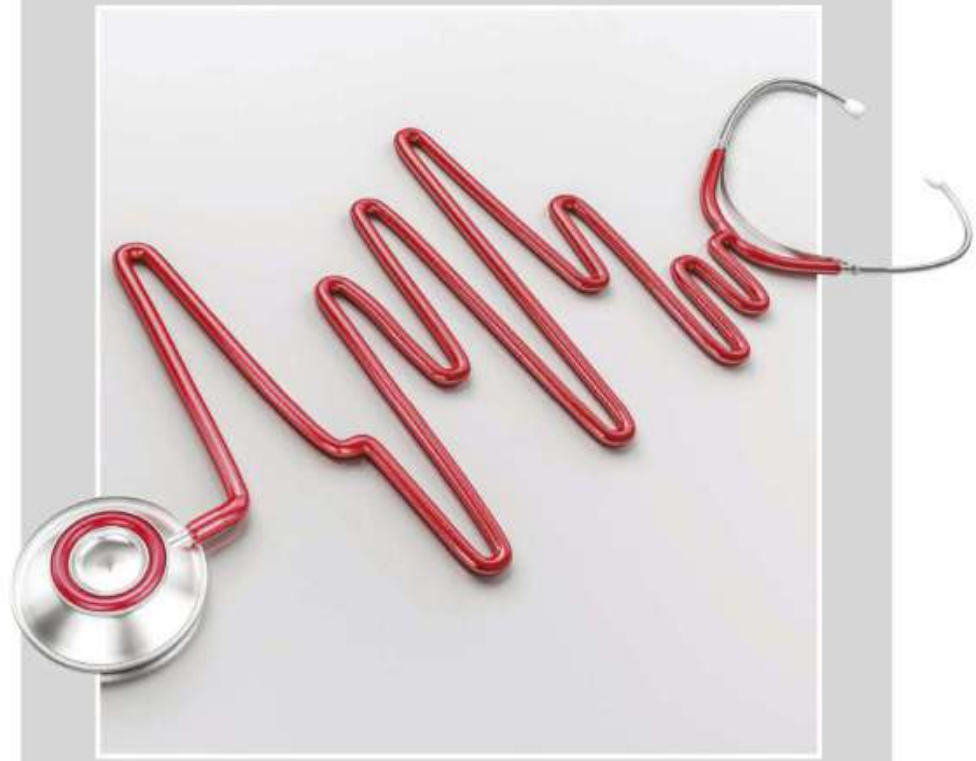
For the answers, visit **bit.ly/BBCFocusCW**
Please be aware the website address is case-sensitive.

GETTY IMAGES

NEXT ISSUE

THE STRESS TEST

The new metric that can determine how resilient you are.



PLUS

EXPLAINER: WHY DO WE SLEEP?

Sleep expert Dr Alice Gregory reveals the secrets of our snoozing.

THE LIFE OF SLIME

Meet the slime mould: a brainless organism that can remember, solve mazes and perhaps even reveal the structure of the cosmos.

ON SALE 1 OCT

SF

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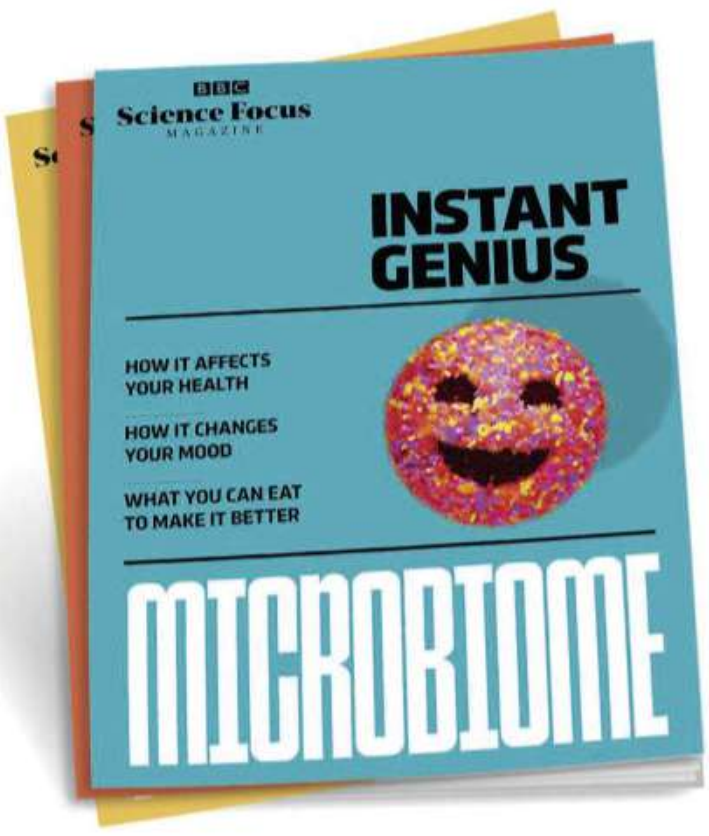

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A SCIENTIST'S GUIDE TO LIFE

HOW TO SIT

STIFF AS A BOARD OR SLOUCHED LIKE A SLOTH? PULL UP A CHAIR AND TAKE THE WEIGHT OFF YOUR FEET AS BACK PAIN RESEARCHER **DR KIERAN O'SULLIVAN** EXPLAINS HOW TO SIT

THERE IS NO 'RIGHT' WAY TO SIT.
Interviewers expect you to sit up straight, and if you're on a date, leaning forwards can make you seem interested. But when it comes to preventing aches and pains, there is no 'right way' to sit.

SLOUCHING ISN'T BAD.
People think that sitting upright is good and slouching is bad, but it's a myth. There's no evidence to support this. A big study in Australia, for example, found that if you follow people through life, the ones who develop chronic back pain aren't the ones who were slouching or who had poor posture. Genetics, anxiety, sleep patterns and stress all play a role.

SITTING UP STRAIGHT ISN'T NICE.
If I ask a room of people to show me the right way to sit, they'll all sit up straight. If I then ask them to stay like that for a while, they'll tell me they can't because it's uncomfortable. We all realise this, yet we're quick to suggest that sitting upright is the best thing to do. I think this has a lot to do with aesthetics. Sitting upright is more socially acceptable than slouching.

FIND THE BEST POSITION FOR YOU.
Although bad posture doesn't cause back pain, if you do experience a bit of pain, I think it's perfectly reasonable to play around with your chair and find a better way to sit. Your pain should settle and then you can go back to sitting how you want.

THERE IS NO 'MAGIC CHAIR' TO PREVENT BACK PAIN.
We've looked at lots of types of chair, including wobbly versus stable, and with and without backrests. Others have looked at regular desks versus ergonomic work stations. None of these things make much of a difference. If they do help, the effects tend to be short-lived as the novelty soon wears off. My advice is, if you are pain-free and sitting comfortably, you don't need a new chair. If you have persistent pain, you could try different chairs and find the one that's right for you.

GET OFF YOUR BACKSIDE.
Prolonged periods of inactivity have been shown to raise the risk of heart disease, diabetes and other conditions, but we need to be careful. In recent times, there's been a trend to tell people to get up and move around every 30 minutes or so, but this can make those with chronic pain even more aware of their frailty. Instead of forcing people to move at prescribed intervals, I think we should be telling people just to move more.

STANDING DESKS WORK FOR SOME.
Although they've become popular and work well for some people, I wouldn't advise putting them in every office. The evidence tells us that you get as many people with persistent pain from standing all day, as you do from sitting all day.

LOOK AFTER YOURSELF.
If you want to have a healthy back in later life, try not to think about it too much now. Try to live a healthy life. Get a good amount of sleep, manage your stress and do some exercise that you can afford and enjoy. SF

DR KIERAN O'SULLIVAN
Kieran is a senior lecturer in physiotherapy at the University of Limerick, and also researches chronic back pain.
Interviewed by Dr Helen Pilcher.

NEED TO KNOW...

1
Slouching and bad posture will not cause chronic back pain.

2
Standing desks are not a silver bullet for back problems, and can lead to persistent pain.

3
To protect your back, stay healthy, sleep well, and keep moving.

ILLUSTRATION: GABRIEL SILVEIRA

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